MODERN METHODS OF TREATMENT

ELECTRICAL TREATMENT

MODERN METHODS OF TREATMENT SERIES

Light and X-Ray Treatment of Skin Diseases. By SIR MALCOLM MORRIS, K.C.V.O., F.R.C.S.Ed., and S. ERNEST DORE, M.D.Cantab. With 12 Plates. **5s.**

Serums, Vaccines, and Toxines in Treatment and Diagnosis. By WILLIAM CECIL BOSANQUET, M.A., M.D.Oxon., F.R.C.P.Lond. **7s. 6d.**

Organotherapy: or Treatment by Means of Preparations of Various Organs. By H. BATTY SHAW, M.D.Lond., F.R.C.P. **6s.**

The Open-Air Treatment of Pulmonary Tuberculosis. By F. W. BURTON-FANNING, M.D.Cantab. With Charts and Figures. **5s.**

CASSELL & COMPANY, LIMITED, LONDON, PARIS,
NEW YORK, TORONTO AND MELBOURNE

ELECTRICAL TREATMENT

BY

WILFRED HARRIS, M.D., F.R.C.P.

Physician to Out-patients, Physician to the Department for Nervous Diseases, and Lecturer on Neurology, St. Mary's Hospital; Physician to Out-patients, Hospital for Epilepsy and Paralysis, Maida Vale

ILLUSTRATED

". . . We must take the current when it serves,
Or lose our ventures."
—JULIUS CÆSAR, Act. iv., Sc. iii.

CASSELL AND COMPANY, LIMITED
LONDON, PARIS, NEW YORK, TORONTO AND MELBOURNE
MCMVIII

ALL RIGHTS RESERVED

PREFACE

THIS book has been written with the main purpose of presenting a comprehensive view of the various forms of Electrical Treatment as practised to-day, giving particular attention to the work that may be done in medical practice with a good faradic and galvanic battery. For instance, the great relief that may be afforded in acute sciatica, brachial neuritis, and other forms of perineuritis by the proper application of the galvanic current is, perhaps, scarcely sufficiently appreciated. Explanations have been given as far as possible of the theory of the various forms of current, so that terms such as "high frequency," "alternating current," and "X-rays" shall not be meaningless counters, in the hope that an added scientific interest may increase the zeal of the student and practitioner of electro-therapeutics. Only the figures necessary to illustrate the text bearing on the more important electrical instruments and current diagrams have been included, and further details must be sought in the illustrated catalogues of Schall, Gaiffe, Watson, Miller, Cox, etc. My thanks are due to those who have kindly lent blocks for the illustrations; while, lastly, the addition of a full index will, I hope, increase the usefulness of the work.

WILFRED HARRIS.

WIMPOLE STREET.
March, 1908.

CONTENTS

CHAPTER I

METHODS AND APPARATUS

PAGE

General Indications and Methods for Use of Faradism, Galvanism, Sinusoidal and Pulsating Unidirectional Currents, Static Electricity, and High-Frequency Currents—Faradic and Galvanic Batteries—Shunt Rheostat—Motor Transformer for Sinusoidal Currents—Static Machines—High-Frequency Apparatus 1

CHAPTER II

THE FARADIC CURRENT

Primary and Secondary Faradic Currents—The Faradic Current in Diagnosis—Motor Points 42

CHAPTER III

FARADIC TREATMENT

Malnutrition—Neurasthenia—Traumatic Neurasthenia—Hysteria—Convulsive Tic—Neuralgias—Neuritis — Blepharospasm — Hemiplegia — Disseminated Sclerosis — Tabes Dorsalis — Graves's Disease — Leukæmia — Headache — Dilated Stomach — Visceroptosis — Constipation — Prolapse — Coma — Hysterical Convulsions — Catalepsy . 53

CHAPTER IV

THE GALVANIC, CONTINUOUS, OR DIRECT CURRENT

Leclanché Cells—Electrical Units—Ohm's Law—Batteries and Accumulators—Tests for Polarity—Effects of Galvanism on

CHAPTER IV—(*continued*)

PAGE

the Skin and Muscles—Electrotonus—Combined Faradism and Galvanism—Reaction of Degeneration—Tetany—Myasthenic Reaction 105

CHAPTER V

GALVANISM (*continued*)

Muscular Wasting—Infantile Paralysis — Poliomyelitis — Arthritic Atrophy—Hemiplegia—Neuritis—Facial Paralysis —Sciatica—Brachial Neuritis—Brachial Plexus Injuries—Musculo-spiral Paralysis—Forms of Sensation—Median Nerve Paralysis—Ischæmic Myositis—Nerve Injuries of the Lower Extremity—Tubercular Neuritis—Ascending Neuritis 140

CHAPTER VI

GALVANISM (*continued*)

Optic Nerve—Hysterical Amblyopia—Ocular Paralysis—Trigeminal Nerve—Auditory Nerve—Vagus and Spinal Accessory Nerves — Laryngeal Paralysis — Hysterical Mutism—Laryngeal Epilepsy—Sterno-mastoid and Trapezius Muscles—Hypoglossal Nerve 205

CHAPTER VII

GALVANISM (*continued*)

Multiple Neuritis—Occupation Neuroses—Spasmodic Torticollis—Raynaud's Disease—Chilblains—Graves's Disease —Leukæmia 221

CHAPTER VIII

GALVANISM (*concluded*)

Electrolysis—Theory of Ions—Cataphoresis—Nævi—Superfluous Hairs and Moles—Fibroids—Aneurysm 236

CHAPTER IX

ELECTRIC BATHS

PAGE

The Galvanic Hydro-electric Bath—Method of Using Main Current for Bath—The Schnée Bath—Local Arm and Leg Baths—The Leduc Current—Electric Sleep—Dangers from Electric-lighting Currents 251

CHAPTER X

THE SINUSOIDAL CURRENT

The Dynamo Current—Armatures and Commutators—Pulsating Unidirectional Current—Motor Transformers—DC and AC Motors—High-tension Alternating Current—High-tension Direct Current. 275

CHAPTER XI

MEDICAL APPLICATIONS OF SINUSOIDAL CURRENTS

Sledge Transformers and Shunt Rheostats—Single-phase Current—Polyphase Currents—Hemiplegia—Spastic Paraplegia — Muscular Dystrophies — Electro-magnetism — Ozone 291

CHAPTER XII

ELECTRIC LIGHT BATHS AND X-RAYS

Radiant Heat—Finsen Light—Mercury Vapour Lamp—Ultra-violet Rays—Various Forms of Electric Light—Coloured Light—Röntgen Rays: The Phenomena of a Focus Tube; Various Interruptors; Use of Alternating Current; Use of Static Machine; Current and Vacuum Rectifiers; Estimation and Dosage of X-rays; Fluorescent Screens; Use of X-rays for Screen Work, Photography, and Treatment—Radium 310

CHAPTER XIII

STATIC ELECTRICITY AND HIGH-FREQUENCY CURRENTS

PAGE

Influence Machines and Apparatus—Methods of Treatment—Sparks, Static Induction, Breeze, Static Charging—HIGH-FREQUENCY CURRENTS: Mode of Generation; Apparatus Required; Medical Application 352

INDEX 373

LIST OF ILLUSTRATIONS

FIG. PAGE
1.—Faradic battery (Spamer) 11
2.—Faradic battery (Lewis Jones) 12
3.—Galvanic battery 18
4.—D'Arsonval galvanometer 20
5.—Switchboard for utilising direct main current for galvanisation and faradisation 25
6.—Diagram of shunt rheostat, or volt-selector 27
7.—Direct current motor transformer, producing sinusoidal current 29
8.—Static transformer for alternating current 33
9.—Wimshurst static machine 35
10.—D'Arsonval's high-frequency transformer 36
11.—D'Arsonval's high-frequency transformer and Oudin's resonator 40
12.—Metronome current reverser 143
13.—Simple form of four-cell *or* Schnée bath 258
14.—The Leduc motor 263
15.—Clarke's magneto-electric machine 277
16.—Simple construction for a "sine curve" 280
17.—Diagram of a direct-current dynamo and commutator . 281
18.—Diagram of EMF's of four pairs of coils in series . 282
19.—Connected alternate currents, or pulsating unidirectional current 283
20.—Diagram of single-phase and three-phase currents . 297
20*a*.—Diagram of pulsating unidirectional current . . . 297
21.—Alternate currents in quadrature, or two-phase current 298
22.—Diagram of three-phase alternating current dynamo . 298
23.—Three-phase sinusoidal current motor-transformer . 299
24.—Béclère coal-gas mercury break (motor-magnetic) . . 323

ELECTRICAL TREATMENT

CHAPTER I

METHODS AND APPARATUS

To obtain the best results with the modern methods of electrical treatment, it is of the utmost importance that the practitioner should use the greatest possible care in making his diagnosis of the case presented to him, and should carefully consider the best form and method of applying electricity as a therapeutic agent if he decides upon its use. For more than a hundred years static or frictional electricity has been employed, rude plate-glass machines of small power, or a resin electrophorus, being at first used as the source of the electrical sparks; while during the last half of the nineteenth century treatment by galvanism and faradism came into use, the latter mainly through the results obtained by the pioneer work and ardent advocacy of Duchenne, whose exploration in the almost untrodden field of neurology at that time led to such an enormous increase in the interest taken in neurological science.

These are still the three main forms in which electricity is used in medicine, though the instruments now employed are of far greater precision and power than formerly. Various modifications of these forms of electricity are also used, *static electricity* being applied either as sparks in different ways, or as positive charging of the patient on an insulated stool, or as the negative breeze. *High frequency currents*, like static electricity, are of extremely high potential, yet the discharge differs in consisting of a number of extraordinarily rapid oscillations, the current having therefore no chemical or electrolytic effect. The *faradic current* is an alternating current, yet unequal in its alternations both in rhythm and in force, giving a very jagged, unequal curve if the electromotive force be planned out on a diagram. A much smoother alternating current is that known as the *sinusoidal current*, in which the rate and amount of variation of the electromotive force are perfectly regular, an approximate example of which is the alternating current supplied by some of the electric lighting companies. This sinusoidal current may, again, be altered in form and changed into a pulsating unidirectional current, by a simple device known as a commutator attached to the motor-transformer, or by passing the alternating current through an apparatus which will allow one phase of the alternating current to pass but not the other. This is known as the Nodon valve, consisting of a group of two or four cells with aluminium and lead poles, in which the property of aluminium is taken advantage of in allowing current to pass freely in one direction but not in the reverse. *Galvanism*, or the constant voltaic current, may be used in several ways, either by the labile or the stabile method, or the current may be periodically interrupted or reversed.

The precise methods of employment of these forms of current and their modifications will be treated more at length in the various chapters devoted to that purpose. Enough has been said to indicate that for a complete installation of electrical instruments to cover all the possible varieties of treatment, a large number of different instruments and a considerable outlay of money would be required. One aim of this book is to show in detail what the general practitioner will be able to accomplish for himself with the aid of a good faradic and galvanic battery, which are the only instruments that the average busy practitioner will have the time or opportunity to use. Cases requiring treatment by the electric bath, or by static or high frequency currents, will generally have to be sent for treatment to those possessing a larger electrical installation, and whose time is more given up to this class of work.

Treatment by the faradic current is especially useful in cases where general sensory stimulation is required, as in hysteria and neurasthenia, especially in these cases where cutaneous anæsthesia is a prominent symptom. General stimulation of the surface by faradism is also useful in cases of general flabbiness and anæmia, in rickets, and in cases of suspended animation, as in syncope during the administration of an anæsthetic, or the coma of opium-poisoning or other narcotic drugs. Faradism is also of great service in those cases where muscular stimulation is required, as in all cases of paralysis where the faradic reactions of the muscles are preserved. It is often taught that faradism is indicated for treatment of striped voluntary muscle, and galvanism for unstriped muscle such as the intestines. This is a dangerous error: the galvanic current should never be applied to the mucous membrane of the stomach or rectum for treatment of muscular atony except by an expert, on account of the serious danger of producing electrolysis and ulceration. On the contrary, the faradic current is of the greatest service in the treatment of chronic atony with dilatation of the stomach when applied by means of a special electrode introduced into the stomach, and also in cases of chronic constipation, one pole being introduced into the rectum.

Another valuable example of the class of case in which faradism is often of the greatest benefit is certain cases of neuralgic pain which may persist after muscular rheumatism, lumbago, sciatica, or pleurisy. For the chronic pain in the side, often most severe, which sometimes remains long after all other signs of an attack of pleurisy have passed away, treatment by the faradic current may often prove of the greatest service. In rectal and uterine prolapse also, and in certain cases of enuresis, this form of treatment may sometimes be used with great success. The various methods of treatment best suited for these different conditions will be treated more at length in the chapter specially devoted to Faradic Treatment.

Galvanism, or the constant current, is indicated in those cases where definite chemical change in the tissues set up by electrolytic action is required, rather than the simple stimulation or shaking of the tissues which the faradic or alternating current produces. Thus, the electrolytic action of the constant current is taken advantage of in the treatment of nævi, in the epilation of hair with destruction of the hair-follicles, the electrolysis of uterine fibroids and of strictures, though for these two latter conditions surgical measures are probably much safer and more efficacious. Owing to its more pronounced chemical action the constant current has the power of provoking contraction of degenerated muscle in cases of neuritis or other nerve or spinal lesions in which the trophic centres of the muscles are damaged. Such contraction is produced only at the make and break of the current, especially at the make, and consequently the constant current applied by means of electrodes immediately over the degenerated muscles, with frequent interruptions of the current, is of use in the treatment of such conditions, by keeping up the nutrition of the paralysed muscles and retarding their wasting. This method, in which one electrode—either the negative or positive pole, according to the kind of case—is stroked over the degenerated muscles, is known as the *labile* method.

Stabile galvanism, in which the electrodes are kept applied to the parts that are being treated, and in which the current is allowed to run smoothly in the same direction for several minutes without interruption, is often useful in the treatment of vasomotor disorders, such as Raynaud's disease, "dead fingers," chilblains, exophthalmic goitre, and in other cases where pain is a prominent feature, as in the pain of a subsiding neuritis, in sciatica, brachial neuritis, and rheumatoid arthritis. Sometimes this form of current may also help in relieving spasm, as in spasmodic torticollis, and the occupation neuroses. As an anodyne, the positive pole or anode has the greater sedative effect, and this may be applied over painful spots, as in trigeminal neuralgia. By means of this current, also, drugs may be introduced through the skin into the circulation, by the process known as cataphoresis. Thus, using the anode as the active electrode, cocaine may be applied to render the skin anæsthetic, by wetting the terminal with a strong solution of cocaine, and pressing the electrode on the skin, passing a steady current of 10 ma. for five minutes.

The **sinusoidal current** for treatment is generally obtained from the alternating current electric lighting mains, but it may be produced by means of a small motor-transformer in places where the direct current is supplied, or by using a battery of accumulators. Single-phase and three-phase currents are used, though there is no particular advantage in using the latter, except in some cases where three limbs require treatment at the same time, which may be done by using the arrangement known as Dr. Schnee's bath. The sinusoidal current is an alternating current much smoother in character than faradism, though somewhat similar in its effects. It tetanises muscle, though it is less painful for the same degree of contraction. It is often used for the treatment of atrophied and degenerated muscles, though for this purpose I consider it far inferior to reversals of galvanism, or to faradism. Dr. Reginald Morton advocates the use of a sinusoidal current of very low periodicity, and claims that it produces contraction in degenerated muscle, as in cases of infantile paralysis, much as reversed galvanism does. I use the sinusoidal current chiefly in the treatment of spastic conditions, using arm and leg baths, as in Dr. Schnee's bath, in cases of transverse myelitis, disseminated sclerosis, and hemiplegia. It is in cases of comparatively recent onset that I have seen the best effects produced by this treatment, the rigidity in hemiplegia certainly seeming to benefit considerably, and cases of spastic paraplegia due to disseminated sclerosis, myelitis, etc., often gaining in strength, with a corresponding diminution of the rigidity. I have, however, found no benefit from this treatment in cases of long-standing spastic paralysis where the rigidity is great, as in old cases of hemiplegia, especially if there are marked athetoid movements.

The **pulsating unidirectional** current, which may be produced by modifying the sinusoidal current by means of a commutator on the motor-transformer, or by means of the Nodon valve, will have practically the same effect as a rapidly interrupted galvanic current, such as may be produced by means of an apparatus known as the Leduc motor. It will have electrolytic effects, though somewhat inferior to the smooth constant current, and will be more painful.

Static electricity has for long been recognised in America, and to a less degree on the Continent, as a most valuable therapeutic agent. It has, however, until comparatively recently been looked at somewhat askance in this country, the machines being regarded more as playthings than of real practical benefit in the treatment of disease. This has been due chiefly to the small size of the machines in use. To get anything like really valuable results, large machines must be used, consisting of eight plates of thirty-six inches diameter. These machines with their necessary accessories are costly and take up a considerable amount of space. They require an electric motor to drive them, and consequently are not easily available. Of late years there has been what might be described as a boom in the use of high frequency currents, and a corresponding diminution in the attention given to static electricity, though there can be little doubt amongst unbiassed observers of the greater therapeutic value of the latter. Static electricity may be administered either as positive charging, or as the negative breeze, or in the form of sparks.

The general indications for treatment with this form of electricity are symptoms of neurasthenia, functional headache, insomnia, depression, and functional paralysis and anæsthesia. Its effects are stimulating and invigorating, raising the blood-pressure and increasing the action of the skin. It is said to exert a stimulant action on metabolism; and since the current is unidirectional, resembling galvanism in this respect, it may well be that this form of current may exert a chemical action of that nature on the exchange processes in the tissues. It is especially in cases of low blood-pressure that treatment by static charging is indicated, and persons whose blood-pressure is already high may be made uncomfortable by it.

High frequency currents are supposed by many to have effect on the metabolism, and to be beneficial in cases of gout, rheumatism, diabetes, and anæmia. The general effect of this current is to lower blood-pressure and to act as a sedative in states of mental excitement. It is often useful in cases of neurasthenic headache, especially when combined with light massage to the head. The claims that have been made for its curing cases of gout, rheumatism, diabetes, and pulmonary tuberculosis are unsubstantial, and are to be ascribed more to the enthusiasm of the observer reporting the cases than to any real and lasting benefit accruing from its use. For local treatment of atony and dilatation of the stomach, for chronic uterine diseases, venereal diseases, and piles, similar claims have also been made, with an equal degree of justification. For certain chronic diseases of the skin high frequency currents may undoubtedly have a beneficial effect, as in lupus, eczema, acne, and pruritus, and in indolent ulcers requiring local stimulation. Lastly, for alopecia and commencing baldness, high frequency currents administered to the scalp by means of the vacuum electrode, have been found to arrest the loss of hair and even to cure the alopecia.

For practical purposes there are two methods of administering high frequency currents: (1) by auto-condensation, and (2) by local treatment by metallic points, vacuum electrode, or by the effluve or brush discharge. There is a third method of auto-conduction, in which the patient is placed entirely within a large solenoid, but it is a cumbersome method and has not been found to present any special advantages.

APPARATUS AND OUTFIT REQUIRED

This will be described in the following order:—

1. Faradism.
2. Galvanism.
3. Sinusoidal current and its modifications.
4. Static electricity.
5. High frequency currents.

1. **Faradism.**—It is not proposed here to give in any way an historical review or exhaustive index of all the different kinds of faradic batteries that are being or have been used. I shall give the essentials for an efficient battery, with a short description of two or three forms now on the market. The best type of battery for the practitioner will depend on the conditions of his practice—whether the battery will have to be carried about from patient to patient, or whether it is intended for consulting-room use only. In the majority of cases the battery will be taken to the patient's house for the treatment, and it will therefore be clearly an advantage to have a battery of moderately small dimensions and as light as possible.

The cell that is now universally used to drive medical coils is of the Leclanché type, and I should strongly recommend anyone purchasing a battery for medical purposes, whether for faradism or for galvanism, to have it fitted with dry cells and not wet ones. The dry cells can be carried in any position, and are much lighter, an important point with a battery containing forty cells, such as is often required for galvanism. Moreover, they give no trouble in the creeping of the salts, with erosion of the wires and binding screws, such as wet cells so constantly give. On the other hand, when exhausted, the cells cannot be renewed, but must be discarded, and new ones fitted, a process which must be repeated from every six months to two years, according to the amount of use to which the battery is put. The well-known Obach and Hellesen cells are both good ones; these can be obtained in various sizes for different batteries. For a *faradic battery* one or two cells only are required, but a much larger cell is necessary than is used in most galvanic batteries, as volume of current in the primary coil is required rather than high voltage. This size of cell is usually sold for half-a-crown.

A point of great importance in the production of a smooth current in the secondary coil is that the interruptor hammer should vibrate directly against the iron core of the primary coil. This hammer of the interruptor may be either a rigid rod working against a small coiled spring, or the interruptor itself may be made of a piece of steel spring, the latter form being usually the most convenient, and a high rate of interruption may be maintained with it, giving a fairly smooth current in the secondary coil. With this form of interruptor, the iron core must be a fixture and cannot be withdrawn, weakening of the primary induced current being arranged for by slipping a brass tube over the iron core, thus cutting off the magnetic field from the primary coil. As the brass tube is slowly withdrawn, so the primary coil is excited by the magnetic field, and the primary induced current becomes stronger and stronger, until the maximum is reached with the complete withdrawal of the tube. If the interruptor hammer is a rigid bar, as in the Stöhrer batteries, the other end of the bar must be prolonged beyond the pivot and attached to a coiled spring, the tension of which can be varied by means of a screw. In some German types of faradic battery the interruptor hammer is made to vibrate against a separate small electro-magnet included in the circuit. This is done in order that the iron core of the primary may be made movable, and can be withdrawn so as to diminish the strength of the primary current. The current from this type of machine is, however, not so smooth and steady as in those in which the hammer is attached to a stiff spring and vibrates directly against the iron core of the primary.

One advantage of having a separate magnet for the interruptor, and a movable iron core for the primary coil, is that by complete withdrawal of the iron core there is no longer any magnetic field effect on the secondary and primary coils. The induced current in the secondary coil is now very much weaker, and is produced only by induction from the primary induced current in the inner coil. It is therefore of much shorter duration, and consequently less painful, though good muscular contractions may be obtained by this method. To obtain a current comparable in strength with a medium strength current obtained when the iron core is in use, it will be necessary to push the secondary coil much further over the primary when the iron core is taken out.

The strength of the faradic current obtained from the secondary coil, usually called the secondary current, may be varied in several different ways. This may be done by keeping the secondary coil permanently fixed over the primary coil, and diminishing the strength of the primary induced current either by withdrawing the iron core, or by slipping a brass tube over the iron core. With the latter method the primary and secondary induced currents will be at their strongest when the brass tube is completely withdrawn, but with a movable iron core the currents will be weakest when the core is completely withdrawn. Either of these two methods may be adopted in the case of small and cheap faradic batteries, where economy of space and of cost is desirable.

Such a battery is that known as Dr. Spamer's coil, sold by Messrs. Schall for £1 (Fig. 1). This is a small, compact battery driven by one dry cell, which is said to work for forty to sixty hours. There is a spring vibrating hammer, with a fixed iron core and fixed secondary coil, the variation of the strength of both the primary and the secondary induced currents being arranged for by slipping a metal tube over the iron core. There is a switch for the starting of the battery current, and two pairs of binding screws

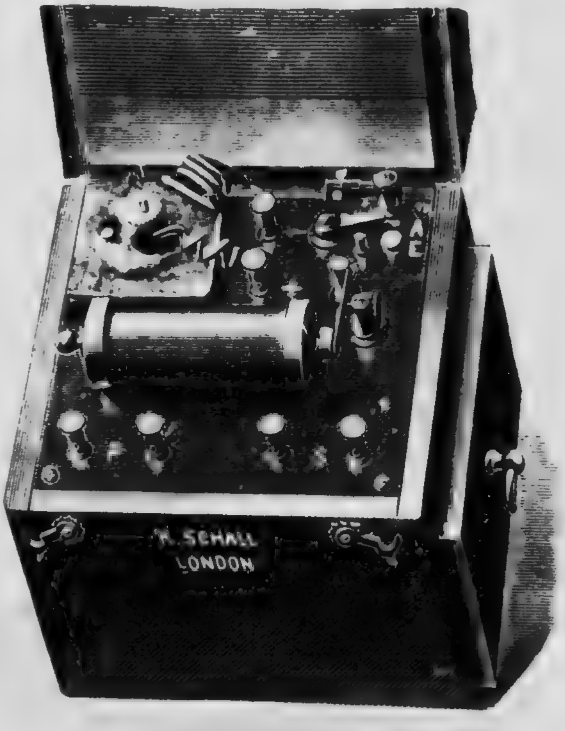


Fig. 1.—Spamer's faradic battery.

for the attachment of the electrode wires for obtaining either the primary or the secondary current.

A third way of regulating the strength of the secondary current is by arranging for the secondary coil to slide over the primary, the current diminishing in strength as the secondary coil is withdrawn from the primary. This is a much more delicate and exact way of graduating the strength of the secondary current, and such coils are known as sledge coils. They take up more space and are more costly than the simpler form of battery previously described. A good example of this form of faradic battery is that designed by Dr. Lewis Jones, usually costing £2 (Fig. 2). It has a spring hammer vibrating against a fixed iron core, and the primary current is not made use of. The secondary coil slides over the primary, and the coil is divided into two unequal parts, each of which is connected to two of three binding screws provided. By this arrangement the current from one-third, two-thirds, or the whole of the secondary coil may be employed, which has certain advantages, as we shall see later. The battery is driven by one large dry cell, said to supply current for eighty hours' working of the coil.

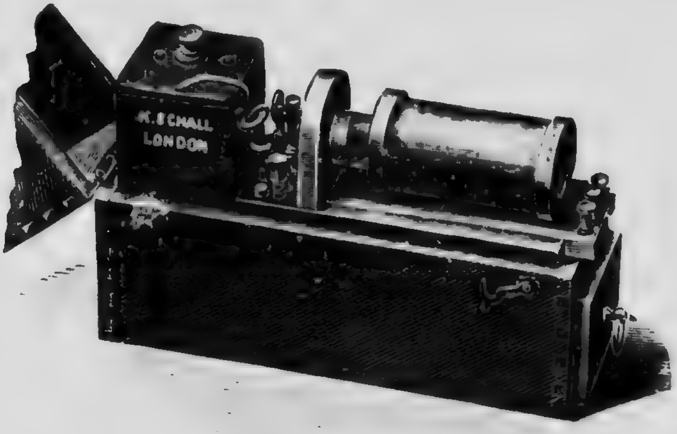


Fig. 2.—Lewis Jones's faradic battery.

Another way of regulating the strength of the primary and secondary currents is by graduating the strength of the exciting current from the driving cell; this is done by means of a starting switch making contact with a series of metal knobs, each connected with resistances of different strengths. Lastly, in some secondary coils with long windings of 10,000 turns, the winding may be tapped at different lengths. By means of a radial switch and five metal knobs attached to the winding at 2,000, 4,000, 6,000, 8,000, and the full 10,000 turns, the strength of the secondary current at the binding screws will vary accordingly. The electromotive force of the induced current in these long coils is higher than in a coil of only a few hundred turns, and the effect of the current on the cutaneous sensory nerves is greater, so that for producing effects of sensory stimulation of the skin it would be better to choose a coil of long winding and to use the coil with the iron core kept in. For producing good muscular contractions with comparatively little cutaneous sensory effect, experiments by Drs. Head and Lewis Jones have shown that with a very high rate of interruptions, 200 to 300 per second, good muscular contractions may be produced without any painful effect at all being produced, so long as the muscle is not strongly tetanised. If the muscle is thrown into strong cramp, there may be severe pain from stimulation of the sensory nerve-endings within the muscle, not from stimulation of the cutaneous nerve-endings.

Tracings of the curve of the electromotive force developed by the induction current of any coil may be obtained by photographing the curves obtained by means of an instrument known as the oscillograph. Dr. Head has found that with currents lasting less than one eight-thousandth of a second in duration no painful effect is produced on the skin.

Unfortunately, we possess no convenient means of measuring the intensity of the faradic current, comparable to the galvanometer which is used for measuring the constant current. The better made and more expensive sledge coils have a graduated scale on the sledge, with a pointer attached to the end of the movable secondary coil, so that the distance through which the coil is moved away from or towards the primary can be accurately measured; and supposing that the driving current of the coil is the same, and that the interruptor is vibrating in the same way, on any two different occasions, then the same intensity of secondary current can be obtained on both occasions by seeing that the secondary coil occupies exactly the same position on the sledge. In practice, the medical man will get to know the approximate strength of the current developed by his coil with the different positions of the iron core or brass slip-tube, and with the different positions of the secondary coil, if his coil is of the sledge type. The strength of the muscular contractions produced by the current in normal muscle will be a good guide, as will the degree of sensory stimulation to the skin when wet electrodes are applied to it.

A good plan will be for the medical man always to make a practice of starting with a weak current, and to try the current upon his own hand first with properly wetted electrodes before applying it to his patient. As soon as he perceives a definite sensory effect, and slight contractions of the hand muscles, he may begin to apply the current to his patient, strengthening it very gradually as occasion arises. Thus the dosage of the faradic current is always uncertain, in the absence of any accurate means of measuring the current, but with a little practice a fair estimate of the comparative strengths of the current required in different conditions can be easily made.

The indications for using the primary or the secondary induced current, and the different methods of using the currents, will be referred to in the chapter specially devoted to the faradic current.

2. **Galvanism.**—For treatment by galvanism a larger and more expensive battery, containing a much larger number of cells, is required than for faradism, though its arrangement will be much less complicated. The simplest form of constant current battery is that known as a patient's battery, consisting of small dry cells, from four to forty in number, arranged in series—that is to say, the positive pole of the first attached by a wire to the negative pole of the second, and so on for all the cells, the two unoccupied poles—the negative at one end of the series and the positive at the other—being connected by wires to metallic plugs in the front of the case, to which the wires carrying the treatment electrodes can be attached. Besides these two plugs, there will also be a number of others connected by wires to intermediate cells in the series, as the third, sixth, ninth, twelfth, and then every alternate cell up to the full number, all these plugs being arranged in a row along the outside of the front of the battery, and numbered 0, 3, 6, 9, 12, 14, 16, etc. In addition, there is figured the sign – at the one end (usually the left) to mark the negative pole, and the sign + at the other end to mark positive pole. With this arrangement the battery can be locked, and need never be opened by the patient or nurse who is given the battery to use, and it is almost fool-proof: an important consideration in a galvanic battery which may be given into the charge of persons totally ignorant of electrical matters; for if the cells or their connections are meddled with, the battery is very easily put out of order, and will be completely spoilt if the terminals at the two ends of the series of cells be short-circuited by a wire joining them, even for a few minutes, or if the wires of the treatment electrodes, when the battery is in use, be allowed to remain in contact.

These galvanic batteries are filled with small dry Leclanché cells, size about 4 in. by $1\frac{1}{2}$ in. by $1\frac{1}{2}$ in. Each cell, when new, has a voltage or EMF of 1·5, and an internal resistance of about .3 ohm. The cells should be either "Hellesen" or "Obach," as these last better than most others. A battery of twenty-four of these cells when new will, therefore, give a current of about 36 volts, which will be sufficient for most purposes of treatment. Yet occasionally a greater voltage will be needed, as in cases of sciatica, when it may be required to send a current of 20 ma. or even more through the limb from the buttock to the foot. In such a case the resistance of the patient's skin and tissues will probably be not less than 3,000 ohms, and by using the formula $C = \frac{E}{R}$, where C = the current in ampères, E = the voltage of the battery, and R = the total resistance of the battery, electrodes, and patient's skin and tissues, it will be seen that in order to obtain a current of 20 ma. it will be necessary to use a battery of not less than forty new Leclanché cells. As the cells get older, and the more they are used, so their voltage falls and at the same time their internal resistance usually increases, and thus the efficiency of the battery diminishes. It will thus be seen, from the equation above given, of what great importance it is, in order to get the greatest possible strength of current out of a galvanic battery, that the factor R shall be kept as low as possible, and this will be best done by seeing that the patient's skin and the electrodes are thoroughly wetted (best with bicarbonate of soda solution) and that the electrodes are kept in close apposition to the skin. With care in this direction the total resistance may sometimes be brought down to 2,000 ohms or even less, and the strength of current obtainable through the patient's tissues is thus proportionately higher. For the treatment of facial paralysis, where only a small current of about 3 ma. is required, the patient's resistance may be brought as low as 2,000 ohms or less, using one electrode applied behind the ear and the other stroked over the face, and for this purpose a small battery of six, or even four, cells will be sufficient.

With such batteries are usually supplied wires and electrodes for treatment, consisting of a flat flannel-covered leaden electrode and a circular covered pad fitted to a handle. The wires are flexible, cotton- or silk-covered, about four feet in length, and one will have a forked end in order that the number of cells in use may be gradually increased two at a time without interrupting the current. This wire should always be used on the right-hand side of the battery.

There is a considerable difference in the prices of these batteries as marked by different makers. Since the retail price of the cells is 1s. 6d. each, and the battery connections are simple and inexpensive, an 18-cell battery should not cost more than £2, nor a 40-cell battery more than £4. These batteries are necessarily heavy, a 40-cell battery weighing 30 lb. The more finished galvanic batteries, fitted with a current collector and a current reverser, such as would be suitable for the medical man himself to use both for diagnosis and treatment, are necessarily more expensive, a 32-cell costing between £6 and £7, or with a small D'Arsonval galvanometer £2 more.

The type of battery shown in Fig. 3 is more finished-looking and more presentable than that previously described. The cells are hidden from view by a polished switchboard, carrying a current collector consisting of an ebonite base fitted with a number of separate metallic knobs placed close together in the form of a ring, each of which is connected underneath with the carbon of one of the cells, in regular order, while another wire connects the zinc of the first cell to the negative binding screw. A crank, connected by a wire to the positive binding screw, and pivoted in the centre of the ring of knobs by means of a spring contact, can be brought into connection with any one of the knobs, which are placed close together so that the crank contact in passing from one knob to the other is in contact with two knobs at the same time, in order to avoid interrupting the current while more cells are thrown into action. Care should be taken, however, not to leave the crank in connection with two of the knobs for more than a moment, as while it is in this position the second cell is being short-circuited. In the circuit are

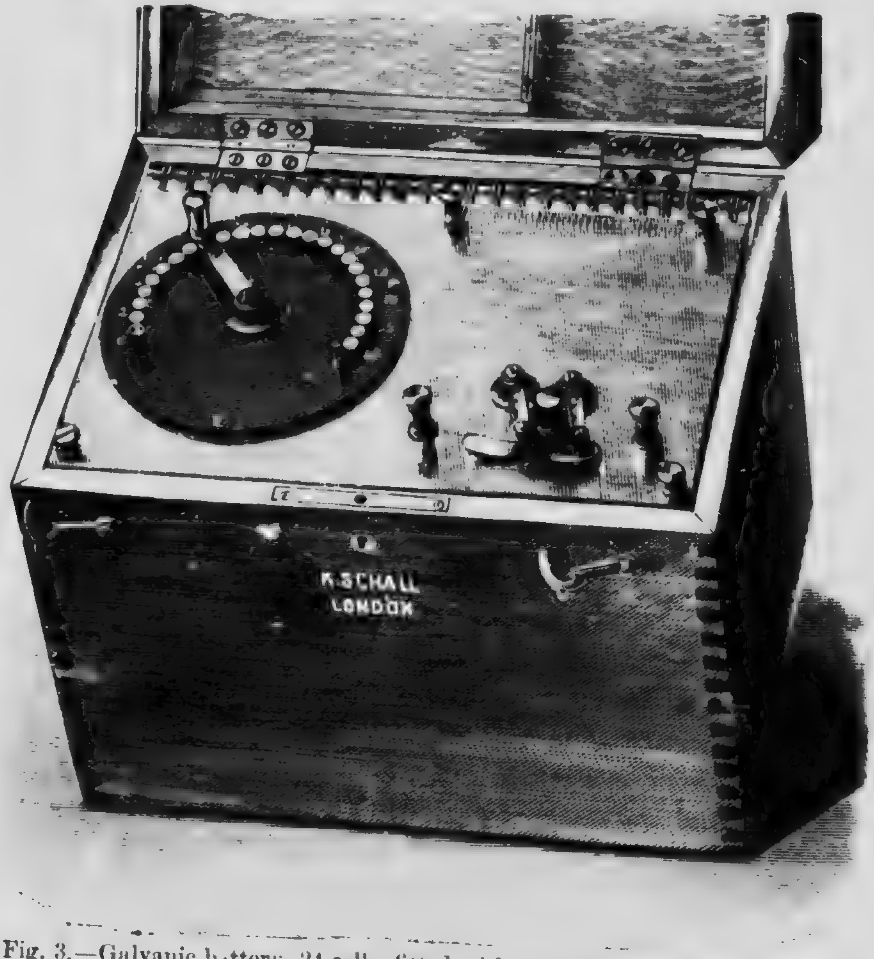


Fig. 3.—Galvanic battery, 24 cells, fitted with current collector and current reverser, and space for galvanometer.

also placed two other binding screws for the attachment of a galvanometer if desired, or, if this is not wanted, the screws may be joined together by a wire.

A galvanometer is a valuable addition to the battery. The best form is that known as D'Arsonval's, the small size, graduated to read to five milliampères, with a shunt to make it read also to fifty milliampères, being obtainable for £2. These galvanometers are dead-beat that is to say, the needle indicating the current on the graduated scale moves at once to the point, without oscillating backwards and forwards before coming to rest, as do those galvanometers in which a permanent magnet is employed. In the D'Arsonval galvanometer no permanent magnet is employed except to surround the working parts and protect them from outside magnetic influences, and they are therefore independent of the earth's magnetism, and can work in any position, and are uninfluenced by neighbouring magnets or electric lighting currents or dynamos.

The principle on which they work was first suggested by Lord Kelvin, to replace the permanent magnet of the old type of galvanometer by a solenoid, a long coil of very fine wire wound on an aluminium frame, and suspended so that it can move freely between two points. The frame is attached to two hair-springs, which always bring it back to the zero position, and a needle is also fixed to the frame as an indicator, which moves over a graduated scale. When a current circulates in a neighbouring coil of wire, another current is induced in the solenoid, and the latter is attracted or repelled according to the polarity of the inducing current. The shunt is an arrangement by which, by means of turning a screw, nine-tenths of the inducing current can be short-circuited away from the inducing coil, so that the solenoid is now influenced by only one-tenth of the current which is actually being used on the patient. The same galvanometer scale may thus read from 1 to 5 ma., or from

10 to 50. Larger galvanometers are made with two shunts, for tens and hundreds, the same scale then reading for 5, 50, or 500 milliampères, according as to whether no shunt is being used, or that for one-tenth, or for one-hundredth (Fig. 4).

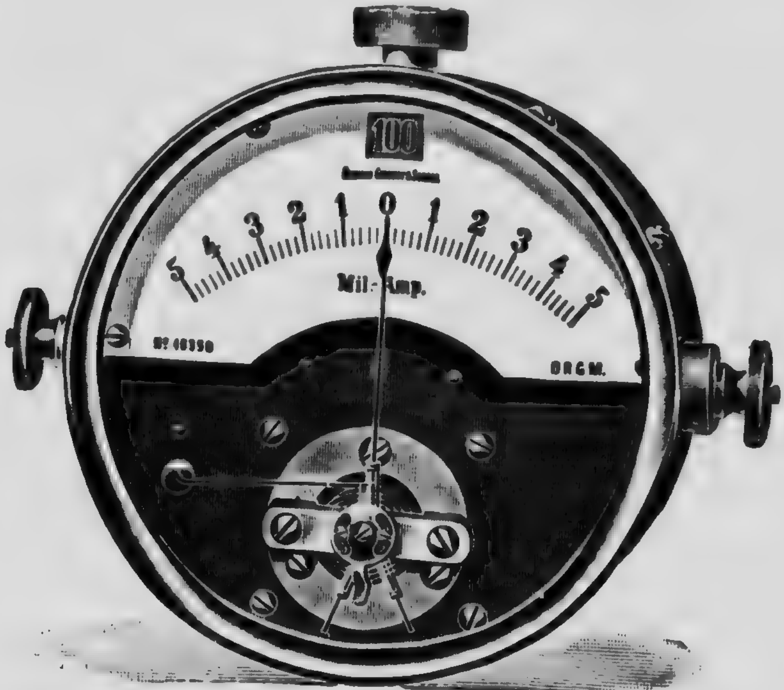


Fig. 4.—D'Arsonval galvanometer, with shunt, reading to 5, 50, or 500 ma.

The older type of galvanometer, in which a permanent magnet was suspended upon a steel point, should be entirely avoided, as they are far more troublesome and very inaccurate owing to the great friction at the pivot and the constant breakages of the needle-point on which they are suspended. Another type, the floating galvanometer of Schulmeister, is fairly accurate and requires no attention, but, like all the horizontal galvanometers using a permanent magnet, it will work only in the horizontal position, and is not dead-beat, requiring several seconds before the needle comes to rest—a great nuisance in practical electro-therapeutics. The current reverser fitted on the switchboard is necessary in the diagnosis of the condition of wasting muscles, and is also often of use in treatment.

The electrodes necessary in the equipment of the battery are two flat pad electrodes, about 6 inches by 3 inches, and two circular pad electrodes about 1 inch and 1½ inch in diameter. For treatment of facial paralysis I prefer a narrow flexible electrode, ½ inch in width by 2 inches in length. It will be advisable to have three or four spare circular pad electrodes which can be screwed on to the treatment handle when required. The form of covering I prefer is chamois leather, as when thoroughly wetted it retains the moisture better than webbing, and slips more easily over the skin. It will be advisable to have fresh covering fitted on to the electrode for each patient, and this can easily be done at home.

The wires to connect the electrodes with the battery should be each about 5 feet in length. Those usually sold for this purpose are covered with cotton or silk, one red and one green in order to distinguish the poles, and attached at both ends to rigid metal pins for connection to the binding screws of the battery and electrodes. These I consider unsatisfactory for several reasons: the metal pins are difficult to attach to some binding screws which are not pierced, or if the hole is not large enough to receive the pin; the flexible copper core inside the cotton or silk covering, made up of a sheaf of fine wires, is very liable to break at its junction with the rigid pin, so that the current is interrupted without any break being obvious; the wires are comparatively costly to renew. Wires covered with cotton alone do not insulate the current properly, especially if wetted, and when the wires touch the uncovered skin of the patient considerable pain may be caused at the point of contact.

The best wire connections in my experience are made of ordinary electric-bell wire, the copper wire core being covered with rubber, with an outside coat of waxed cotton. A dozen yards of this may be purchased for sixpence, and it is the matter of only a few minutes to cut two lengths of four or five feet and remove the covering from the copper wire core for the last inch at each end. This form of terminal can be easily fastened securely to any binding screw, and the end is easily renewed when broken; and when the wire becomes too short, or if it gets broken in the middle, a new length may be cut from the reserve. Should the current fail after everything has been arranged for the treatment and the switch turned on, it will be advisable to test the wires before examining the cells inside the battery, after first looking at the binding screws to see if they are screwed up tight. The best way to test the wires is to attach one to a binding screw of the constant current battery, and turn on the crank of the collector four or five cells; then with the other end of the wire, after pulling the wire taut with the hand, momentarily to touch the other binding screw. If the galvanometer indicates the passage of a current after testing each wire, the wires are probably intact, and the fault cannot have been in the battery or wires, but must have been in the electrodes, or in their mode of application to the patient. Occasionally, however, even this mode of testing may fail at the first attempt to locate the faulty wire, as the wire may be broken and yet the broken ends may be kept in close apposition by the silk covering most of the time that it is being used, giving a jerky, interrupted current that is most objectionable to the patient.

Two batteries are thus necessary to the practitioner —a faradic battery, such as that designed by Dr. Lewis Jones, and a galvanic battery, preferably of thirty-two cells, or even forty, the latter being fitted with a current collector, current reverser, and D'Arsonval galvanometer, with two pairs of wires, and several treatment electrodes.

Such an outfit will cost £2 for the faradic battery, and £8 12s. for a thirty-two-cell galvanic battery. For the same total cost, exactly, a combined battery could be bought, containing the faradic apparatus, though of a less efficient design, and thirty-two cells for galvanism, and the galvanometer, with current collector and current reverser. This combined battery will, however, be necessarily much heavier than either of the other two, and will be far less convenient to use for treatment at the patient's house, as when faradism only is required, instead of the small and compact faradic battery only being taken, the same heavy combined battery has to be carried on all occasions.

A combined battery, of somewhat better design, will be very useful for consulting-room work for those practitioners who have experience of batteries and of the technique of muscle-testing. In such a combined battery the faradic apparatus, sledge coil, interruptor, and starting switch are usually arranged on one side, with two large dry cells in a separate compartment underneath to drive the coil, while in the centre of the switchboard will be placed the single or double collector for the galvanic current, a rheostat, galvanometer, current reverser, De Watteville commutator, and two binding screws in front for the attachment of the electrode wires.

The De Watteville commutator is a convenient switch, by means of which either faradism from the induction coil or galvanism from the collector may be led to the same pair of binding screws, avoiding the necessity of changing the wires. It is usually arranged so that when the commutator is directed to the left, marked G, the galvanic current is led to the electrodes, and when turned to the right, marked F, the faradic current is obtained.

When the commutator is placed exactly in the midway position, both currents are at the same time led to the electrodes. By an arrangement of the wire connections beneath the switchboard, the secondary coil is then placed in series with the cells supplying the galvanism, the faradic current thus passing through all the galvanic cells, and the galvanic current passing through the coil before reaching the electrodes. The resistance thus experienced by each current before its exit from the battery will diminish a little the intensity of the available current, yet it is occasionally useful to apply in treatment combined faradism and galvanism in this way. It is, however, important that, before using his battery in this way, the practitioner should test for himself to see that the coupling up of the faradism and galvanism has been properly done by the electrician before sending the battery out. The negative pole of the one should be connected to the positive pole of the other, the electrodes being connected to the two extreme poles. If this is done, it can be easily demonstrated that with a given strength of faradic current its tetanising effects upon muscle are much enhanced by turning on a galvanic current of about three milliampères.

This is best seen when the interruptor of the coil current is made to vibrate quite slowly, so that the individual contractions produced by each faradic shock are just visible. The addition of a comparatively weak galvanic current by this process of "galvano-faradisation" makes the individual muscular contractions produced by the faradic shocks much stronger. This is due to a local condition of katelectrotonus set up in the neighbourhood of each electrode. It is useful to be able to make the interruptor of the coil work quite slowly sometimes, which can be done by means of an aluminium bent wire fitted on to the top of the interruptor, with a sliding weight. This can be so adjusted, by screwing up or unscrewing the contact point of the interruptor, that any desired speed between two and 40 interruptions per second can be obtained.

In districts where the continuous current is available for electric lighting it will be convenient to make use of it in consulting-room practice for faradisation a [illegible] lvanisation by means of a suitable switchboard (Fig. 5). This may be made either of polished wood, slate, or marble,

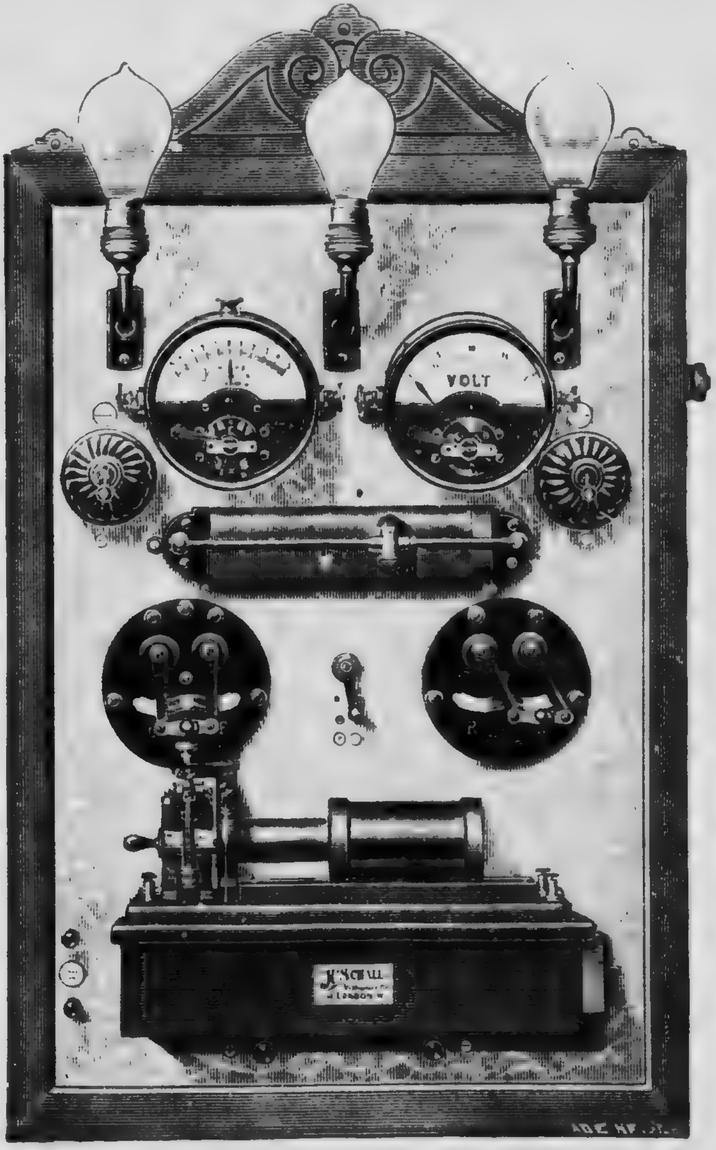


Fig. 5.—Switchboard for utilising the direct main current for galvanisation and faradisation.

The figure shows, from below upwards, Faradic sledge coil, De Watteville switch, faradic key, reversing key, shunt rheostat or volt selector, faradic and galvanic switches, galvanometer, voltmeter, and three resistance lamps.

either of the latter being preferable to wood in districts where the voltage of the electric supply is from 200 to 250. The current is led on to the switchboard from a wall-plug, two 16-candle-power lamps being interposed as a resistance for the faradic apparatus, if the voltage is 100 volts, and 32-candle lamps being used with the higher voltage.

The current, after passing through the two lamps, is led to an ordinary faradic apparatus with interrupting hammer, primary coil, and secondary sledge coil, etc. For galvanism, the current from the main is led through a resistance of a lamp of 8- or 16-candle-power, according to the volume of current required, and thence to a volt-selector. This consists of about 500 turns of insulated platinoid wire wound tightly on a slate bed, the insulating material being sand-papered off the surface of the coils of wire, leaving the sides of the coils still insulated from each other, the total resistance of the coils of wire being not less than 500 ohms. A spring contact sliding on a metal bar can be slid along over the coils, and the wires carrying the main current are connected, one to each end of the platinoid coil (Fig. 6).

Two other wires connect the right-hand end of the platinoid coil and the rigid bar of the sliding spring contact to the two binding screws for the attachment of the wires leading to the patient. The patient is thus placed in a shunt circuit, and the apparatus may be called a shunt-rheostat, or a volt-selector. The galvanometer is inserted in the circuit between the sliding spring contact and the left-hand binding screw. While the sliding spring contact is at the right-hand end of the platinoid coil, the EMF. in the patient's circuit is only a small fraction of a volt, and this is gradually and steadily increased, without any jumps or shocks, as the sliding spring is pushed along the bar towards the left, the available voltage being proportionate to the voltage of the main supply and the candle-power of the lamp used in the resistance. Thus, with a 100-volt supply and a 16-candle-power lamp, the maximum voltage available in the patient's circuit is about 65. The galvanometer is of the D'Arsonval type, and should be fitted with a shunt enabling it to read to 5, 50, or 500 ma.

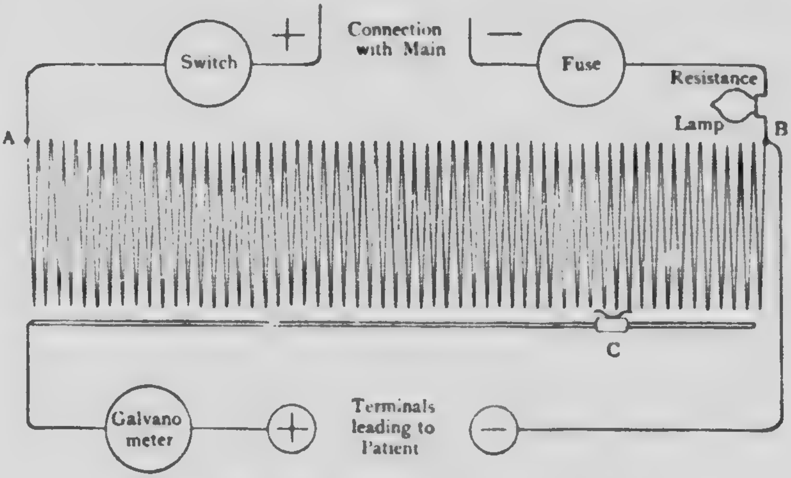


Fig. 6.—Diagram of shunt rheostat, or volt-selector.

A voltmeter may also be fitted, if required, and there are a De Watteville commutator for faradism or galvanism, and a current-reverser for the galvanism. This apparatus is very convenient for applications of faradism and muscle-testing in consulting-room practice, or for local applications of galvanism, as for the treatment of wasted muscles. The same apparatus may be obtained in a portable box form, with an adaptor plug and cord for fixing on to a lamp socket, so that the battery can be used wherever there is a constant current main supply.

If, however, larger currents of 15 or more ma. are to be used, as for the treatment of sciatica, for electrolysis, or for the electric bath, then there is a certain amount of risk of inconvenience or even danger in thus using the main current from the direct current supply. This is due to the liability to sudden interruptions of the current or partial temporary failure of the supply, owing to faults occurring either at the power station or in the underground cables. Such sudden interruptions in the voltage [illegible] he current supplied would cause quite unpleasant sh[illegible] to the patient if a constant current of even 10 ma. were being applied; while if such currents were being applied in the neighbourhood of the head or neck, or if a general electric bath were being given, the results might even be serious. Besides these accidental causes of interruptions of the current, interruptions are liable to occur, usually at stated times of the day, owing either to changing from one machine to another, or to the switching on of a battery of accumulators. To obviate this risk of shocks, either a battery of Leclanché cells should be used for the administration of constant currents of 8–10 ma. or more, or else a battery of accumulators, which may be charged in the consulting-room itself from the main, through a suitable resistance. (*See* pp. 111 and 270.)

3. **Sinusoidal current.**—By this, as we have said, is meant an alternating current whose curve of electromotive force in both positive and negative phase varies perfectly constantly and smoothly, in what is known as a sine curve. For all practical purposes the current from the electric lighting mains, in those districts supplied by an alternating current, is a sinusoidal current, and it may be made use of after passing it through various transformers, to be described presently. In those districts which are supplied by the direct or constant current, or where a battery of accumulators is available, a sinusoidal current may be obtained for treatment by the use of a motor-transformer, the motor being wound according to the voltage of the continuous current supply available, such as a 12-volt motor for accumulators, or 100-, 200-, or 240-volt motor for the direct electric lighting currents. Such a machine, to produce a single-phase alternating current, with the addition of a sledge transformer to vary the strength of the sinusoidal current gradually, costs about

£1., (Fig. 7). A similar machine, for producing three-phase sinusoidal currents, with three sledge transformers, costs £6 more.

In these motor transformers the direct current is led into the armature of a direct current motor, revolving in the field of an electro-magnet. Wires from two opposite points of the armature are led on to two collector rings, from which a single-phase alternating current is taken off. If three-phase sinusoidal currents are required, a third collector ring must be added, and the winding of the armature must be equally divided into three parts, one end of each being connected to one of the three slip rings, while the other three ends are joined together. Owing to the reversal of the direction of the current that is induced in the upper and lower halves of the armature by the magnetic field, the current that is obtained from the two slip rings which are connected to the two halves of the armature is an alternating or sinusoidal current. The voltage of this current will be proportionate to the voltage of the current that is used to drive the motor, as $1 : \sqrt{2}$. The efficiency of these small motors will be about 60 per cent., and for a 240-volt direct current a sinusoidal current of about 150 volts will be obtained.

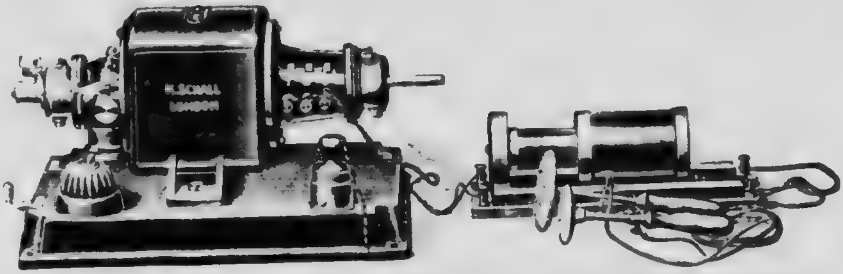


Fig. 7.—**Motor transformer, to utilise direct main current, producing sinusoidal current.**

The motor is provided with three slip rings, and is wound for producing three-phase sinusoidal current. Only one sledge-coil transformer is shown, attached by wires to two of the slip rings, thus providing a single-phase sinusoidal current at the electrodes.

This current will not be safe from the risks of earth contact through gas or water pipes, just as when using the direct main supply current, on account of the connection with the direct current through the armature of the motor-transformer; therefore, if this sinusoidal current is to be used for bath treatment it must be re-transformed in a sledge coil. This is exactly the same in principle as the primary and secondary coils of a faradic battery. The alternating current from the two slip rings is led into the inner fixed coil, and the outer coil of wire, wound on a quite separate bobbin, is slipped over the inner coil, and can either be fixed thus in position, or can be made to slip off the inner coil along a sledge, thus diminishing the voltage of the current induced in it. Owing to the current that is supplied to the inner coil being already alternating, no interruptor hammer and magnet are necessary as in the faradic apparatus, and an alternating current is induced in the outer coil having the same periodicity and type of curve of electromotive force as the alternating current that is led out of the motor-transformer. This current from the sledge coil, being entirely out of contact with that from the main, is perfectly safe for bath treatment, and there is absolutely no risk of shocks from accidental contact with gas or water pipes.

If a commutator be added to the transformer, the currents that are induced in the upper and lower halves of the armature may be led to the two slip rings so that their polarity is the same, instead of reversed, as it is when a sinusoidal current is produced. With this commutator in use, a pulsating unidirectional current, or what may be called a sinusoidal constant current, is produced. By means of a switch, either a sinusoidal or the pulsating unidirectional current may be led to the sledge-transformer. With this latter current a galvanometer may be included in the circuit, so that the current may be measured, though if the sinusoidal current is used the only means of measuring the strength of the current is by means of a hot-wire milliampèremeter.

Another modification that may be fitted to these transformers is the Leduc reverser, so that a rapidly reversed galvanic current is obtained. By means of an arrangement by which the collecting brushes of the Leduc reverser can be shifted in position, the period of contact with the galvanic current during the reversals may be either long or short. This rapidly reversed galvanic current by means of the Leduc motor produces tetanic muscular contractions just as faradism or the sinusoidal current does, but with the brushes arranged for maximum contact the current is much more painful for the same degree of contractions, even when a low voltage of galvanism is used. The pain may be considerably diminished if the collecting brushes are so placed that the period of contact during the reversals is at a minimum. The curve of the electromotive force of this current will, of course, somewhat resemble that of the sinusoidal current, but will be much more jerky.

When a third slip ring is added to the transformer, and the winding of the armature is equally divided into three to give a three-phase sinusoidal current, then three sledge coils must be used for the regulation of this current, and three wires and three electrodes are necessary for the treatment. This is a very useful and pleasant way of applying the sinusoidal current with local bath treatment, as in Dr. Schnee's bath, to one arm and both legs, or other similar arrangement. Thus, with three electrodes, A, B, and C, there is a current from A to B, another from B to C, and a third from C to A. With such a transformer and group of three sledge coils, a single-phase current may be employed at any time, if preferred, by using any two of the three sledges, and the corresponding binding screws, wires, and electrodes connected with them. On the whole, the three-phase method of application is less painful than the single-phase.

These motor transformers may be combined in the same wall-apparatus, for consulting-room work, with that for the application of galvanism and faradisation, so that with such an apparatus a variety of currents may be used: *faradism*, of varying speeds of interruption; *galvanism*, with slow interruptions by hand, or with rapid reversals by the Leduc reverser; a *pulsating unidirectional* (or sinusoidal constant) current; and single-phase or three-phase *sinusoidal* currents.

In districts which are supplied by alternating current for electric lighting, this main current may be made use of by a comparatively simple and cheap apparatus for the application of single-phase sinusoidal current for either local or bath treatment. This current, which is circulating in the street mains at a pressure of 1,000 volts or more, is led into a stationary transformer, built somewhat on the principle of a faradic coil, as soon as it enters any building. This transformer is always situated in a cellar, or similar position, and is usually enclosed in a strong wire cage, so that it shall never be interfered with by unauthorised persons, as the current running in the wires which lead into the street, being at a pressure of 1,000 volts or more, is highly dangerous to life. In this transformer the voltage is reduced to 200 or 100, and after passing through fuses and the meter, is led throughout the building. Thus, in the consulting-room the alternating current is available from a wall-plug or lamp-socket, and the only apparatus necessary for its use in application to patients for local treatment is a sledge-transformer, costing £2, or a volt-regulator the latter, with fuse, lamp for signal and safety resistance, and mounted on slate, costing £4.

For bath treatment a similar apparatus is necessary, with the addition of a stationary coil-transformer, costing five guineas (Fig. 8). This coil-transformer, as has already been explained, is added in order entirely to isolate the current used for treatment from the current in the main, so that there shall be no danger from accidental earth contact through gas or water pipes, or electric switches.

Magneto-therapy.—Though absolutely no physiological effects are produced by the action of the strongest electro-magnets excited by the direct current, yet, if powerful alternating current magnets are used, definite results are obtained. When the patient approaches such a magnet, alternating currents are induced in his body, and owing to the stimulation of the retinæ flashes of light are seen, a sensation of warmth is felt, and it is said that headache and other neuralgic pains may be diminished. Such treatment is said to have a great sedative effect and to promote sleep. Such magnets require to be worked by heavy currents up to 40 ampères, and cost about 10 guineas.

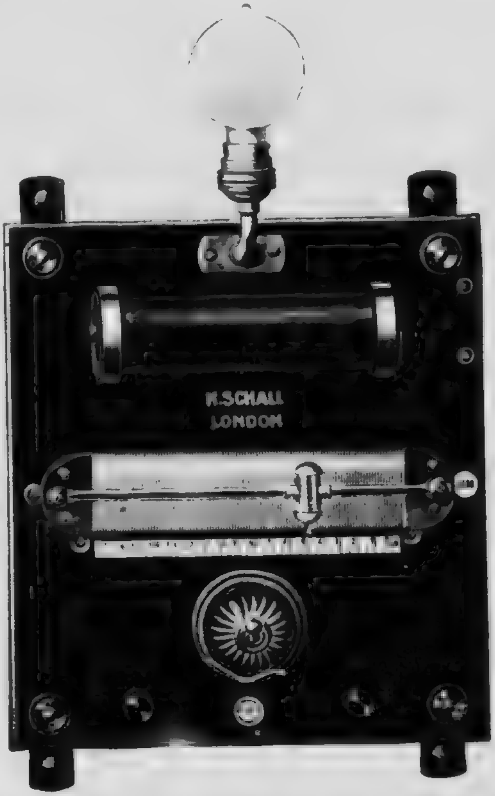


Fig. 8.—Transformer for alternating current, with volt-selector, for bath treatment.

4. **Static electricity.**—For treatment by static electricity, the Wimshurst type of machine is universally employed in this country. The details of its mechanism need not be gone into here; suffice it to say, that large machines are necessary to produce satisfactory results, not less than eight glass plates of 30 inches diameter being advisable, while 36-inch plates are preferable. The voltage of the current obtained depends on the diameter of the plates and on their speed of rotation, while the volume of the current, or number of milliampères, depends on the diameter of the plates and on their number.

Various forms of Wimshurst machines are made by different makers, those by Gaiffe and other Paris makers usually having ebonite instead of glass plates. These French machines are generally built without a glass case; but in this country, at any rate, an air-tight glass case is absolutely necessary, the air inside being kept dry by a dish of calcium chloride. The advantage of using ebonite instead of glass is that they may safely be run at a high rate of speed without risk of fracture of the plates; while glass plates, especially of large diameter, may break at a high speed, owing to the great centrifugal force developed at the periphery of the plate. Ebonite, however, is liable to buckle and to deteriorate in course of time, its insulation suffering, and therefore the output of the machine diminishing. A good static machine, with eight glass plates of 36 inches diameter, will cost 40 guineas (Fig. 9). In addition to this, the case will cost from £10 to £15; the set of electrodes, including jointed handle, head breeze, with connecting and earth chains, another £5 or £6. A strongly-made polished platform to carry the patient's chair, mounted on varnished glass legs at least 12 inches long, is also necessary, and is often included in the price of the machine.

The machine is best driven by a DC electric motor of ¼-horse-power, costing from £8 to £10, but the pulleys may be geared to a pair of pedals worked bicycle fashion. The total cost of such a machine, mounted on ball bearings, with the necessary apparatus, will thus work out at not less than £75, as a rule, while for 12-plate machines the cost is proportionately larger, a ½-horse-power motor being usually required to drive them.

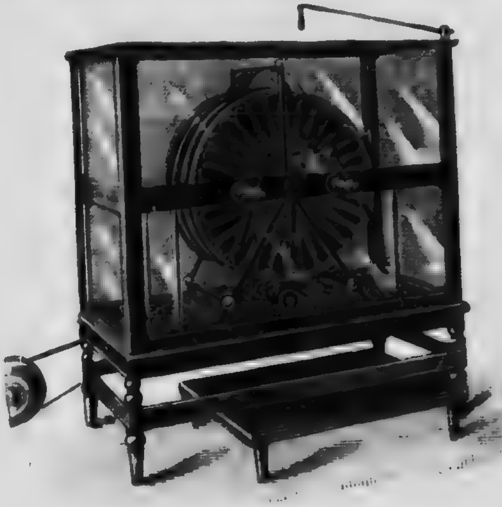


Fig. 9.—Eight glass-plate Wimshurst static machine in case. (Messrs. Watson.)

A well-made large static machine, such as that described, will also be available for X-ray work, a very steady light being produced on the screen, though the output is not so great as that from a good coil, and longer time will be necessary for exposure for photographs. The static machine may also be used, with the addition of Leyden jars, spark gap, and copper solenoid, to produce high frequency currents. Such a transformer as D'Arsonval's costs about £5 16s. (Fig. 10).

The machine is used by one pole, usually the positive, being connected to the patient, who is seated upon an insulated platform, while the other pole is connected to earth by a light chain attached to a water or gas pipe. The electrodes, also attached by a light chain to earth, can then be handled by the operator without risk of shocks. The platform should be stoutly built, about 42 inches by 27 inches in size, supported by stout, well-varnished glass legs 12 inches high. The edge of the platform should be surrounded by a raised wooden beading to prevent a chair slipping off, while no metal points or sharp wooden edges must be permitted, all the surfaces being carefully smoothed and rounded, in order to minimise the loss of the electrical charge through leakage through the air. On the floor of the platform is fixed a brass plate about 12 inches square, for attachment of the chain to one pole of the machine. This chain is attached to one end of an

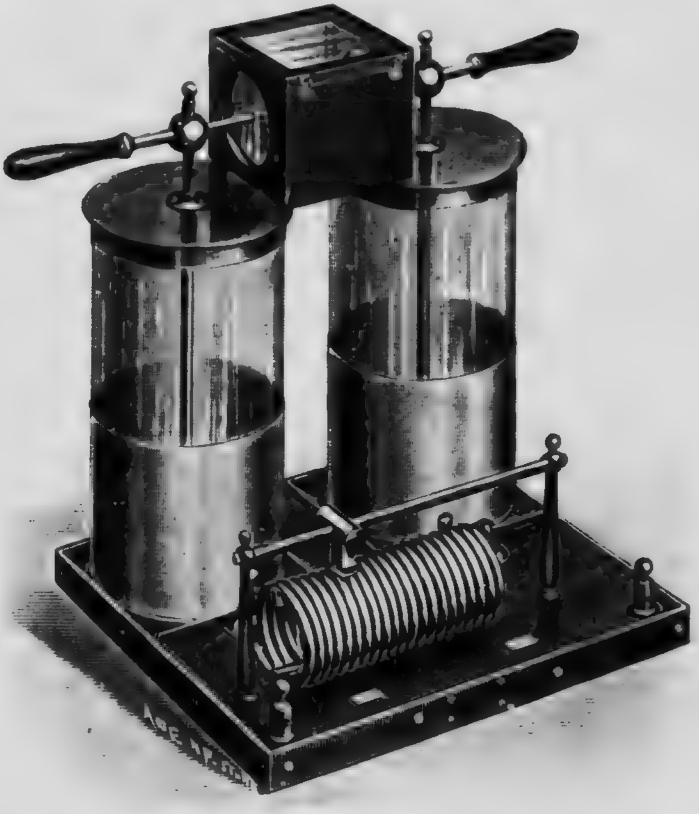


Fig. 10.—D'Arsonval's transformer, showing Leyden jars, spark gap and primary solenoid.

ebonite bar, 12 inches long, ending in two brass knobs, placed between the poles of the machine, the knob at the other end being connected by a chain to earth. The bar is reversible, so that either knob can be applied to either pole of the machine by simply turning the bar through one half-circle. By this device the pole of the machine to which the patient is attached can be reversed at will.

The electrodes are devised for the application either of sparks or of the static electric breeze, and at least five will be found useful: a brass ball and a brass roller electrode for the application of sparks; and a single-point and a multiple-point electrode for the application of the breeze. Another multiple-point electrode is in the form of a metal cap attached to a swinging bar from the top of the case of the machine, so that the cap can be brought into position over the patient's head. The first four electrodes are held in the operator's hand, a jointed handle being also attached to them so that both hands may be used for their support.

It is important to be able to test the polarity of the machine, as either knob of the machine may become positive or negative, although, once the machine is in action, there is little chance of the polarity becoming reversed (*see* p. 357).

In the old type of small static machines, Leyden jars used to be attached to the terminals of the machines in order to reinforce the strength of the sparks; but these are never used with the modern high-power machines, except for the application of the static induced current, by Morton's method, or when, by the use of D'Arsonval's transformer, the static machine is to be used as a source of high frequency currents.

5. **High frequency currents.**—These currents are produced by using the oscillatory discharge of a Leyden jar. When the jar is discharged, what appears to the eye is one single spark or explosion, but in reality there is produced an extremely rapid oscillatory discharge, the

periodicity of which may reach many millions in a second. Two large Leyden jars are used, or a battery of condensers arranged as plates, the inner coatings of which are charged from the terminals of a large induction coil, while the outer coatings are connected together by a helix or solenoid of about twenty turns of thick wire. This solenoid is best made of copper tubing of some $\frac{1}{8}$ inch in diameter, as, owing to the enormously high potential and the rapid oscillations of the currents that are induced in the solenoid, these currents are conveyed almost entirely along the surface of the conducting wire, and scarcely at all in the centre of the wire. This is known as the " skin effect."

When the jars are being charged from the induction coil, they discharge across the spark gap between the two terminal knobs in a stream of brilliant crackling sparks, while at the same time extremely rapid oscillatory currents at a potential of 100,000 volts or more are set up in the copper solenoid connecting the outer coatings of the jars. Although the outer coatings of the jars are thus short-circuited by means of the copper solenoid, yet, owing to the copper wire, or tubing, being wound in the form of a helix, the current circulating in one coil induces a current in the neighbouring coil, thus, through the electro-magnetic effect produced, enormously increasing the resistance of the solenoid to the passage of the current. The solenoid may, indeed, be compared with the primary coil of a faradic battery, and a derived circuit, formed by attaching wires to the two ends of the solenoid, will afford oscillatory currents just as the derived circuit from the primary faradic coil affords the primary faradic current. These oscillatory currents are known as " high frequency " currents. Another secondary coil may be wound around this primary solenoid, so producing induced oscillatory currents of even higher voltage. In Tesla's transformer the primary consists of four turns of wire wound on a wooden frame of about 12 inches diameter, while the secondary is placed inside the primary, and consists of a long coil of insulated wire wound on an ebonite cylinder. Such an instrument costs about £7, the D'Arsonval transformer with the Leyden jars and adjustable spark gap costing another £5 16s.

Instead of a Tesla transformer, an instrument known as a resonator may be employed to raise the potential of the high frequency currents. That usually employed is Oudin's, consisting of a solenoid of medium-sized copper wire wound round a vertical wooden cylinder of about 8 inches diameter. This may be in series with the copper solenoid of the D'Arsonval transformer, or it may be connected directly to the Leyden jars, a sliding contact varying the number of turns of wire in the circuit until a lively brush discharge appears at the upper terminal of the resonator, while the cord leading to the treatment electrode is attached to a second sliding contact on the resonator, or to the upper terminal. A compact form of apparatus, including two large Leyden jars, adjustable spark gap, and Oudin resonator, mounted on a movable table, costs about £15 (Fig. 11).

Other apparatus necessary are a couch for treatment by the "condensation" method, and variously-shaped vacuum electrodes and single- and multiple-point metal electrodes. The couch is an ordinary bentwood couch with cushions 2 inches or 3 inches thick, on which the patient lies; behind the cushions is a large flat metal plate, which is attached to one terminal of the solenoid, the other terminal being connected to a bare metal electrode held in the patient's hand, or applied by means of a vacuum or metal point electrode. These high frequency transformers, as described, are best driven by a 10-inch or 12-inch induction coil, which may be worked either from the continuous current main through a mercury jet interruptor, or by a battery of accumulators and a Béclère coal-gas mercury break (p. 322). The coil and its condenser and the interruptor must be designed according to the voltage of the constant current supply that is to work it. The same coil that

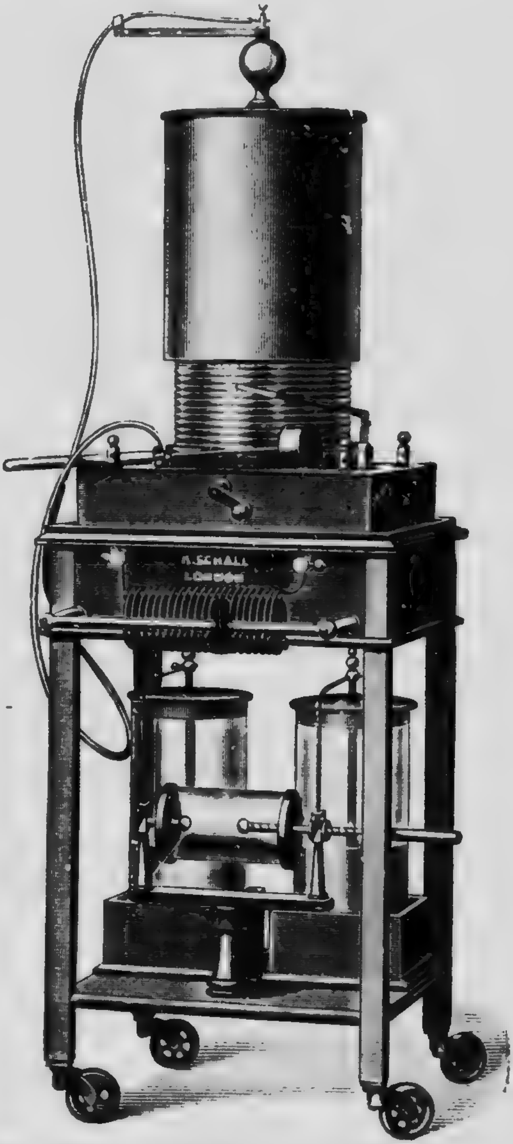


Fig. 11.—High frequency apparatus, combining D'Arsonval's transformer and Oudin's resonator.

the practitioner uses for X-ray work will also be available for producing high frequency currents by means of the

D'Arsonval transformer. In the treatment of patients by high frequency currents a galvanometer is advisable, which is built on the hot-wire principle, measuring up to 800 ma.

Other apparatus which is sometimes used is a couch, for treatment by the method of auto-conduction, in which the patient is enclosed entirely within the primary solenoid. Currents are then induced in the patient's body as they are in the secondary of a Tesia transformer, and a Geissler tube held in the patient's hands will glow brightly, although he can feel no direct effects of the current. Such an installation for the production of high frequency currents will cost from £70 to £80, including the cost of the 12-inch induction coil, which may also be used for X-ray work.

As already stated, high frequency currents may be obtained by using a D'Arsonval transformer with a large static machine, which again will also be available for X-ray work, though it is to be remembered that the output of even a large static machine, either for X-ray work or for the production of high frequency currents, is much less than that of a properly constructed 12-inch induction coil. In electric lighting circuits where the alternating current from the main is available, this source may be used for the production of high frequency currents by means of a step-up transformer, by which the voltage is raised to about 6,000 and then, by means of a spark gap, Leyden jars, and solenoid, high voltage high frequency currents may be obtained. Such an apparatus costs about £25, but the terminals of the step-up transformer are dangerous to life. A very powerful machine for utilising the main alternating current is made by Messrs. Gaiffe, of Paris (*see* pp. 327–28), but it is very costly.

CHAPTER II

THE FARADIC CURRENT

The primary current.—The term "faradisation" was invented by Duchenne for his treatment by the induced current obtained from a small induction coil, after its discoverer, Faraday. Such an induction coil consists of a coil of insulated wire wound on a reel containing a soft iron core, with a spring interruptor inserted in the circuit between the cells of the battery and the coil, to break the battery current rapidly and regularly. The coil requires a current of about 300 ma. to work it satisfactorily, and is usually driven by two, or sometimes three, Leclanché cells of large size, which may be either wet or dry cells. The current from the cells, being rapidly interrupted by the mechanical spring contact, and circulating in the coil around the soft iron core, rapidly magnetises and demagnetises the latter, thus setting up a rapidly varying electro-magnetic effect in the field surrounding the iron core. Comparatively speaking, the magnetisation of the core is developed slowly, whilst its demagnetisation at the break of the battery current is sudden, and therefore the current that is induced in the coil of wire around the magnetic core is produced practically only at the break, and is therefore a unidirectional current which flows in the same direction along the wire as the battery current.

Another reason for the negligible quantity of the induced current developed at "make" is that it is developed in the contrary direction to the battery current, and is thus resisted. The unidirectional induced current at break is what is known as the primary faradic current, and, reinforcing the battery current, produces the spark at the contact breaker. By means of a derived circuit formed by joining two wires to the two ends of the coil, the induced current can be made available for treatment. It is of a very much higher voltage than the battery current which is responsible for its production, and partly owing to this reason, and partly to the high self-induction of the neighbouring turns of the coil, this current will flow through the derived circuit and through the high resistance of the patient's skin and tissues, although the alternative closed circuit of the coil and cells is available for it. The battery current, at the low pressure of about 3 volts, is altogether confined to the closed circuit of the primary coil and cells, none of it making its way through the far higher resistances of the derived circuit and the patient's skin.

The secondary current.—So far we have spoken only of the primary coil, and the primary faradic current, which is not the form of faradism that is most used in medical treatment. In most induction coils there is also a second coil, consisting of a much larger number of turns of finer wire, wound on a reel or bobbin, and placed over the primary coil. It may be either fixed in this position, or, as in the better class of coils, made to slide on and off the primary coil, the varying distances of the secondary coil from the primary being shown on a measured scale. These are known as sledge coils. The rapid rise and fall of the magnetic action exerted around it by the primary coil causes the appearance of induced currents, of high potential, both at make and break in the secondary coil, that at break giving very much the stronger shock. This current at break in the secondary coil is of higher voltage than that at make, owing to the fall of magnetic action being more sudden than its rise. As previously said, this slower rise of the magnetic action of the primary coil is due to the comparatively slow magnetisation of the iron core owing to the battery current at make being resisted by an induced current in the opposite direction in the primary coil.

The "secondary" faradic current, or the induced current at make and break in the secondary coil, is thus really an alternating current, but of unequal waves, and practically for purposes of muscular or cutaneous stimulation it is the current at break which produces all the effects. Strictly speaking, the amounts of current at make and break in the secondary coil are equal, as judged by their chemical effects or their action upon a galvanometer; but, owing to its lower voltage, the induced current at make has much less appreciable physiological effect. As we shall see later, it is this lower voltage current at make which is the chief cause of the hardening of the X-ray tubes when driven from a large induction coil, it being then known as the "closing" current.

When the iron core is withdrawn from the primary coil it will act as a solenoid only, and the strength of the primary induced current will be much diminished, while its electro-magnetic action on the surrounding helix of the secondary coil will fall to a corresponding degree, so that the induced secondary currents both at make and break will be much weaker than when the iron core is inserted in the primary coil. The iron core has little or no direct magnetic action upon the secondary coil, as practically all the lines of magnetic force from it are cut by the wires of the primary coil.

The two currents compared.—The induced current is more rapidly developed and is of shorter duration when the iron core is withdrawn, and it has much less painful effect upon cutaneous nerves for that reason. The larger the number of turns of wire in the secondary coil, the less quickly are the waves developed and the longer their duration, so that a coil with a large number of turns produces a greater effect upon sensory nerves than one with a small number of turns. Conversely, when painful stimulation effects are not desired, as in muscle-testing, it will be best to use a secondary coil with a comparatively few turns of wire, and to withdraw the iron core.

A common proportion that is used in practice is 700 turns of comparatively stout wire in the primary coil, and 5,000 turns of a finer wire in the secondary.

It is sometimes useful to have two secondary coils, which can be interchanged, or else a long coil of 10,000 turns which can be tapped at different lengths. Thus, I use a coil of 10,000 turns, which is tapped at 2,000, 4,000, 6,000, and 8,000 turns by a small radial switch and five metallic studs, so that any desired length of the coil can be used at will.

Strength of the secondary current.—The regulation of the strength of the secondary faradic current in the better class of medical coils is effected by sliding the secondary coil off or on to the primary, the maximum current being obtained when the secondary is exactly over the primary. In the smaller and cheaper coils, the secondary coil is not provided with a sledge, but is fixed in position over the primary, and the strength of the current is regulated by slipping a brass tube over the iron core within the primary. When this brass tube is in position, the iron core is prevented from exerting any magnetic influence upon the primary coil, and there will be only very weak primary or secondary faradic current obtainable, while with the brass tube withdrawn both these currents will be at their strongest. Unfortunately, we have no ready means of accurately measuring the strength of the faradic current. Being an alternating current, it has no effect on the needle of an ordinary galvanometer, and its ampèrage is too small to affect an instrument working on the principle of a hot wire, like the milliampèremeter in use with high frequency currents. There are one or two clumsy instruments available for measuring faradic currents, but none convenient enough for general use. Meanwhile, by experience of the particular battery in use, one gets to know roughly the proper position of the sledge coil or of the brass tube, according to the type of battery, that is required to produce the necessary physiological effect.

Another convenient way of guessing approximately at the strength of the faradic current produced by the coil in any given position is to test its effect with properly wetted electrodes upon the skin of one's own hand, before applying the current to the patient, and again to test the degree of muscular contraction of the muscles of the thenar eminence by applying one electrode to the ball of the thumb, the other being held in the closed palm of the other hand. Indeed, it is a good rule always thus to test the strength of the current before applying it to the patient, and if this rule is insisted on, we shall avoid giving the patient an occasional dose of maximum current for which neither he nor we were prepared. The way in which this accident usually occurs is by the small switch which is provided with the better medical coils for changing from the secondary to the primary current, getting out of place. This switch is moved from one knob, marked P, usually placed to the left, to another knob, marked S, close beside it on the right, and it is very easy for the switch to be moved over to P from S without the operator being aware of it, either by an accidental touch, or by someone else having touched the battery, perhaps for cleaning or dusting purposes. It should, therefore, be made a rule always to look at the position of this switch before commencing treatment with faradism, because if the switch is turned towards P, and the iron core is pushed home, the maximum strength of the primary current will be administered, whatever is the position of the secondary coil.

It should be remembered that in the regulation of the strength of the primary faradic current the position of the secondary coil has no effect upon it, the primary current being varied in strength by pulling out the movable iron core. In those batteries where the iron core is fixed and acts as the magnet for the hammer of the interruptor, the primary current is weakened by pushing in the brass tube which slips over the fixed iron core.

Choice between primary and secondary currents.—Since Duchenne's time, fifty years ago, various indications have been laid down to govern the choice between the use of the primary and the secondary faradic currents in treatment. It has been commonly said that the primary current should be used for the stimulation of deep-lying organs, as the stomach, bladder, rectum, and intestines, while the secondary current has more effect upon the limb muscles and in stimulating the cutaneous sensory nerves. For use in an electric bath the primary current should be chosen. Personally, I invariably use the secondary current for all purposes of cutaneous and muscle stimulation, whether of the skeletal muscles or of the viscera. I have found, by experiment on cats, that the secondary faradic current acts excellently in stimulating the motor nerves to the bladder and rectum, the animals being under anæsthesia by chloroform, and also that the muscular walls of the stomach, bladder, and rectum contract well in tetanus when the electrodes are applied directly to them.

[illegible]

The faradic current as a means of diagnosis.—The use of the faradic current in the diagnosis of neuromuscular conditions is invaluable. When both nerve and muscle are healthy, with a rapidly vibrating interruptor and a sufficiently powerful current, if the electrodes, properly moistened, are applied to the skin over a motor nerve, such as the facial nerve behind the ear, all the muscles supplied by the nerve are thrown into active tetanic contraction. The contraction is developed sharply and suddenly, and ceases as suddenly on the stoppage of the current. The reaction of the nerve to faradism is then said to be normal. If a muscle be wasted from long disuse, or from a disease causing slow wasting, as in a lesion of a neighbouring joint, or in a case of myopathy or progressive muscular atrophy, then the briskness of the faradic reaction is diminished, and the contraction is less in quantity, and is both developed more slowly and relaxes less quickly. When there is a lesion of a nerve, as in a facial neuritis or Bell's palsy, the nerve soon loses its excitability to faradism, and if the lesion be a severe one, the muscles will no longer contract at all when faradism is applied over the nerve. This is the reaction of degeneration in the nerve, its excitability being lost at the same time both to faradism and to galvanism. The condition takes a few days to develop, and is often preceded by a wave of hyperexcitability passing down the nerve from the site of the lesion towards the periphery. Thus, one or two days after the development of a facial palsy, it is sometimes possible to demonstrate this hyperexcitability of the nerve by applying the electrode in front of the ear over the parotid, when the reactions of the facial muscles to the faradic current will be brisker, and developed with a weaker current, on the side of the lesion than on the sound side.

Although the secondary faradic current is an alternating current, yet the waves are unequal, that developed at break being far the stronger, and it is therefore possible to speak of a kathode and anode for the faradic current as in the case of galvanism. As in the latter form of current, the contraction is produced more strongly at the kathode. When there is a severe nerve-lesion, no reactions will be obtained to faradism if the electrodes are applied to the skin over the muscles in the ordinary way after the lapse of a week to ten days from the time of the nerve injury. If, however, in these cases needles thrust into the muscles be substituted for the ordinary pad electrodes, some contraction will be seen around the negative pole, even in cases of advanced wasting with reaction of degeneration of the muscles.

In cases of spastic paralysis, such as the late rigidity of hemiplegia and spastic paraplegia, the normal briskness of reaction of the muscles is somewhat altered, the contraction being rather more slowly developed and not relaxing so suddenly. Sometimes in hemiplegia or in paraplegia, due to a transverse lesion of the cord, the muscles waste at first rather rapidly, and are flaccid; and unless a faradic battery were at hand to take the electrical reactions it would be easy to mistake such a case for a lesion of the lower neuron, such as a poliomyelitis, or a neuritis. In either of the two latter conditions, after the lapse of a week from the commencement of the symptoms, the faradic reactions of the muscles will be much diminished, or lost altogether. If the faradic reactions, on the other hand, are normal, it is certain that the lower neuron is intact, and that the lesion, if any, is affecting the pyramidal fibre in the cord or brain. In functional paralysis, also, the reactions of the muscles to faradism will be perfectly normal. In the majority of cases of infantile paralysis, or acute anterior poliomyelitis, the paralysis at first is more widespread, and many more groups of muscles may be temporarily paralysed than ultimately results. Thus the whole of one lower extremity may at first be completely paralysed for two or three weeks, though permanent wasting may only occur in some of the groups of muscles below the knee, especially the tibialis anticus and extensors of the toes, with perhaps partial wasting of the quadriceps extensor femoris. The thrombotic and hæmorrhagic lesion in the anterior horns of the spinal grey matter that has destroyed the trophic centres of these muscles, has at the same time temporarily paralysed through shock the neighbouring centres for the remaining muscle groups of the lower extremity, and occasionally such functional paralysis of these remaining muscles may persist even for months if untreated.

It is in such cases that faradism is so useful in diagnosis, for those muscles whose trophic centres are destroyed and are permanently paralysed will not react to faradism, while those muscles whose voluntary power is merely temporarily inhibited through shock will react briskly to faradism. Thus the electrical reactions, taken from a week to ten days after the onset of the paralysis, will give an unerring prognosis as to the true and permanent extent of the paralysis, though without this test the only way of deciding on the extent of the permanent paralysis is to wait for the onset of atrophy in the stricken muscles.

If, then, a muscle responds with a brisk contraction to the faradic current, it may be taken as certain that the lower motor neuron supplying that muscle, anterior horn cell, anterior root, and the mixed nerve to the muscle is intact. The converse proposition does not always hold good, for sluggishness of contraction to faradism may be present in cases of reflex wasting of the muscles from joint disease, —arthritic atrophy as it is called—also in myopathy, in chronic cases of spastic paraplegia, and in hemiplegic rigidity; that is to say, in cases where the lower motor neuron is uninjured, or even at times when the limb and muscles are cold and stiff. Further, in total transverse lesions of the cord, the muscles of the lower extremity may waste rapidly, and lose all their electrical reactions both to faradism and to galvanism, although no lesion whatever of the lumbar grey matter or peripheral nerves may be discoverable *post mortem*.

Motor points.—In the testing of muscles electrically, there are certain points on the skin, known as *motor points*, which on stimulation give the maximal contraction for the particular muscle. These roughly correspond to the point of entry of the motor nerve into the muscle, and though they are subject to a certain latitude of variation in their position in different subjects, they are sufficiently constant to be charted, and Erb has published charts of the motor points, which are usually copied into books dealing with electrical treatment. There is, however, no necessity to remember these points, or to use such charts in electrical testing, for it is far better to find the motor point of the muscle that is being examined for oneself, which is easily done by stroking the testing electrode over the muscle while faradism is being applied, the site whence the maximal contraction is obtained being the motor point.

Of the limb muscles the two motor points that are most likely to give trouble in finding are those for the extensor hallucis longus, which is low down on the front of the leg not far above the ankle-joint, and that for the pronator radii teres, which is generally best obtained at a point just internal to the biceps tendon at its insertion into the radius. The corresponding muscles of the two sides will always react in almost an identical manner to the same strength of current, so that if only one limb is at fault the reactions of the muscles in the opposite limb should be taken as the required standard.

One electrode, the indifferent electrode, is usually a flat leaden plate, covered with flannel or chamois leather or webbing, and thoroughly moistened with warm water; it is best applied either to the back or front of the chest, or the patient may sit upon it. The active or treatment electrode should be a circular pad about 1 inch in diameter, set on a handle, the pad being similarly covered and moistened. Special testing electrodes are made with a key on the handle for making contact. If such is used, care should be taken that the key is so fitted as to " make " the contact, and not to break the current. Personally, I prefer not to use a special testing electrode, but an ordinary treatment electrode of the size mentioned, and to interrupt the current by placing the finger on the vibrating hammer of the induction coil while with the other hand holding the electrode on the muscle to be tested. In this way single induction shocks may, if thought necessary, be used. In many of the testing electrodes supplied, the insulation of the key is insufficient, and there is a leakage of current, while if the method I use be adopted there can be no question of the interruption of the current. The testing electrode should not be made too small; 1 inch in diameter is quite small enough for all purposes except testing the tongue and palate. When testing the interossei or some of the facial muscles, the edge of the electrode may be used, and in testing the intrinsic muscles of the hands or feet, the indifferent electrode is better placed on the palm or sole, so as to send the current through the part.

It has been suggested to make testing electrodes with one handle carrying the two electrodes, of very small size, placed quite close together; it is, however, a bad plan to have the two electrodes close together on the skin over a muscle, as the current then does not penetrate properly, and it will be found that a much stronger and more painful current is necessary to produce the required contraction than when the indifferent electrode is placed at a distance.

CHAPTER III

FARADIC TREATMENT

GENERAL MALNUTRITION

The faradic current may be used in the treatment of atonic muscular conditions, as in emaciation resulting from long illnesses, rickets, anæmia, etc. That daily applications of faradism over a period of weeks may stimulate metabolism beneficially has been proved by its effect on the growth of young animals, a litter of puppies being divided into equal numbers and kept under precisely the same conditions as regards surroundings and diet, but one of the groups being exposed to treatment by the faradic current daily for twenty minutes. Those treated by this means after several weeks weighed considerably more than those untreated, although previous to the experiment the differences were inappreciable.

The best way of applying the current in cases of general malnutrition is by means of the electric bath, the patient being immersed in a warm bath and the two electrodes connected to the secondary coil, one large, flat electrode being placed behind the patient's back, and the other at the feet. Many cases of severe rickets have been reported as improving remarkably under this treatment, as have also cases of chlorosis and other forms of anæmia, and cases of prolonged debility following long illnesses, such as influenza, septicæmia, typhoid fever, empyema, and other causes of chronic suppuration, etc.

It may be said that general electrification applied in this manner, using faradism from the secondary coil in the electric bath, may be a most useful adjunct to the ordinary methods of treatment of such cases when they are not getting on well. Thus in chlorosis iron is sometimes very badly tolerated, either causing severe headaches or indigestion. Although, when this is the case, tolerance of the drug may sometimes be procured by being careful to administer it always soon after food, and in very dilute form—either as a chalybeate water, or by adding half a tumblerful of water to each dose of the iron mixture—yet occasionally cases are met with when improvement is either very slow or the condition may even remain stationary. The addition of arsenic to the medicine should then always be tried, but sometimes the treatment by the faradic bath may start improvement when everything else has appeared to fail. The same may be seen in rickets, or in weakly, puny, anæmic children, whose digestion is very irregular and who do not gain in weight and size as they should do normally for their age. After typhoid fever and influenza, prolonged debility is quite common and is sometimes accompanied by considerable mental depression and loss of memory, lack of initiative, and general failure of the mental powers. Here also general electrification by faradism may be of the greatest benefit.

NEURASTHENIA

By this term, which we owe to an American physician, Dr. Beard, who described the condition in 1879, is meant a condition of nervous weakness, nervous debility, or nerve exhaustion which occurs in subjects of both sexes, usually of adult age, most frequently between the ages of thirty and fifty. It has often been ascribed to the hurry and stress of modern life in cities, but that this is untrue needs only a little experience of such cases, a considerable proportion occurring in men and women of leisured habits, upon whom the strain of competition for a living or for social success bears but slightly. On the other hand, it is sometimes said that neurasthenia results from such men and women having too little to do, that it is due to their excessive leisure allowing them time for too much self-introspection and consequent dissatisfaction with themselves, thus engendering the morbid symptoms of what may be called the disease neurasthenia. Though I have no doubt that this is a predisposing cause of a certain degree of importance in a certain number of cases, those who have the large experience of a hospital out-patient department will be struck at once by the large number of cases occurring both in men and in women who are fully occupied, but yet not manifestly overburdened, by the ordinary duties of life. This condition of nervous weakness is, then, due to some congenital or hereditary inability of the higher intellectual centres to face the everyday problems and emergencies of ordinary life—a breakdown of their powers, that in many cases is temporary, though in many others the normal capacity is never recovered, as though the machinery had become prematurely worn out.

Traumatic neurasthenia.—A very important group of cases of neurasthenia is that known as "traumatic neurasthenia," occurring in persons who have received a definite injury, often not in itself severe, but yet which has exerted a profound effect upon the nervous system of the sufferer, who is usually, in this group of cases also, of "neurotic habit" and congenitally prone to nervous weakness. A certain proportion of these cases, which may follow accidents, such as railway accidents, and are often classed as cases of traumatic neurasthenia, are accompanied by definite symptoms of paralysis and anæsthesia, and other hysterical stigmata, which will be described separately under the heading of Hysteria (p. 62).

A sub-group of cases of traumatic neurasthenia of especial interest is formed of cases following head injuries, usually slight concussions, frequent enough as the result of falls in the hunting field or of driving accidents. Here the injury is sufficiently severe to cause definite injury to the brain, consisting of meningeal ecchymoses, and superficial hæmorrhages and lacerations of the brain substance itself. In more severe cases, fractured base, depressed fracture of the skull, and larger meningeal hæmorrhages, cause more or less prolonged loss of consciousness, to be followed later, after the graver symptoms have subsided, by neurasthenic symptoms of the most aggravated type.

In the large majority of the cases following injury, if the appropriate treatment is carried out for a sufficiently long time, the prospects of ultimate complete recovery are good, as there is often no congenital weakness of the higher intellectual centres, which we have seen to be so important a part of the development of ordinary cases of neurasthenia. In these traumatic cases the injury to the brain resulting from the concussion produces the same condition of instability of these centres; but, as the lesion may be recovered from, so the prospect of recovery from the neurasthenia it produces is good. It is, however, most essential that prolonged mental and physical rest should be enjoined upon patients suffering from symptoms of traumatic neurasthenia as the result of head injuries, a year's withdrawal from all mental fatigue and excitement being often necessary as a preliminary to the resumption of the ordinary duties of life.

Cases of traumatic neurasthenia.—Three instances of traumatic neurasthenia will suffice as examples, the symptoms giving a typical clinical picture of the disease. In the first, E. W., *æt.* 34, a market-gardener in a large way of business near London, was driving a light van one morning in London, when he was run into by an omnibus, and was thrown from his seat from a height of 8 feet into the roadway, striking his left hip and spraining his right knee severely and ricking his back. His head was not injured, but he was very stiff as a result, and could not move for several days. Ever since the accident he has felt depressed, with loss of memory, forgetting everything quickly, and he has the utmost difficulty in keeping his accounts. Complains of a sensation as if a half-hundredweight was pressing on the right side of the back of his head. The headache spreads from the right side of the back of his head over the vertex, and becomes more severe about three times a week. Walking seems to affect his back, so that his legs drag. Has occasional dizziness, as though he were going to fall. Any noise worries him intensely, such as a train whistle, or the noise of the children in the house, and he has become very irritable. Since the accident he finds great difficulty in keeping awake, and has become a very heavy sleeper, especially for the first few weeks after the accident. He has no energy now, and he seems to dread all the details of his business. Physical examination of the nervous system elicited nothing abnormal, save some tenderness over the third lumbar spine, eight months after the accident, though the neurasthenic symptoms persisted. This was the first day he had been in London since the accident, and he had not seen an omnibus in the interval; but the sight of them in the streets, he says, made him feel quite sick with fright. In this patient there were two causes which aided in prolonging the period of his mental and physical collapse. Firstly, his too early return to work, which was forced upon him, as he had no one to take his place in the business and look after his men; and secondly, the mental strain and anxiety produced by prolonged negotiations between his solicitor and the omnibus company on the question of compensation.

Legal negotiations on the question of compensation for alleged injuries following an accident are a frequent cause of the prolongation of the symptoms of a traumatic neurasthenia which it is often the aim and object of the defendant company to describe as malingering. Of late years, however, the clinical entity of traumatic neurasthenia has become generally recognised, not only by the medical profession, but by judges who have had experience in railway accident and other compensation cases. The early disappearance of the symptoms in a proportion of the cases after the legal negotiations have been completed, whether satisfactorily in a financial sense to the plaintiff or the reverse, is no proof of the symptoms having been due to malingering; and it is an undoubted fact that a residuum of cases do not get well, but remain in a permanent condition of nervous instability and inability to work.

A good example of the cases which get well after compensation I saw in a doctor, a big Irishman of 6 ft. 4 in., who was sitting in a train that was run into from behind by an express. The noise and confusion were terrific, and many persons were severely hurt, but he himself escaped without any bodily injury. He lost his nerve, however, completely, and a few days later gradually developed a typical hysterical left hemiplegia, with hemianæsthesia and loss of the special senses on the left side, and with contracted visual field on that side, amblyopia, and unilateral loss of colour-vision. The latter symptom he was not aware he possessed, for with both eyes open he could recognise colours perfectly. The presence of this symptom without his being aware of the fact was alone sufficient to disprove the theory of malingering, which indeed was not put forward. While the legal negotiations for compensation with the company were proceeding he was unable to attend to his practice, which was fast disappearing, and he was thinking of selling it. He was getting worse instead of better, and a certain degree of incontinence of both sphincters developed. Yet, within a week of his claim being settled by the railway company, he began to improve, and he rapidly got well and was able to resume his practice. Many would, no doubt, be tempted to declare this to be a case of malingering, yet I am perfectly certain it was not so.

With this may be contrasted a similar case which occurred in the case of a navvy, *æt.* 35, who gradually developed the same symptoms of left hemiplegia, etc., a few days after being struck on the head by a falling brick. The element of compensation was absent here, yet, in spite of treatment at various hospitals, the symptoms persisted unrelieved for four and a half years until I saw him in 1898. He attended for over nine months in the electrical department at St. Mary's, where I treated him with strong faradism administered with the wire brush, with the result of eventual complete recovery. No improvement was seen for the first two months, during which he had on two occasions severe hysterical fits, preventing his attendance for a few days. His very slow recovery, in spite of the most energetic treatment, is an example of the more obstinate persistence of the symptoms in cases which have been already allowed to run on for a long time. He returned to work, earning full wages as a navvy for the next seven years, but has recently developed an hysterical paralysis with contracture of the right hand, following on an accident during his work in excavating a new road, when he was struck in the abdomen by the handle of a barrow, after which he vomited some blood. He was admitted to hospital on this account, and gradually developed the hysterical contracture of the right hand, still complaining for months of pain in the abdomen, though nothing wrong could be discovered on examination. On this occasion he brought a lawsuit successfully against his employer for compensation, eight months after the accident, though the paralysis was much less severe than on the former occasion, and commenced to improve as soon as treated with the wire brush. A feature of the case, excluding malingering on both occasions, was the blueness and coldness of the hand affected with the hysterical contracture.

Traumatic neurasthenia in children.—Traumatic neurasthenia may occur even in children after head injuries. A recent case I have seen in a little girl of five, who was struck on the head by a piece of iron gutter falling from the roof of a house. She was rather badly concussed, and for several months afterwards suffered from symptoms indicative of traumatic neurasthenia. She was restless at night, and was afflicted with night terrors, while in the daytime she was peevish and cross, could not remember anything she was told to do; she preferred to be solitary, being unable to bear the noise of other children playing. Though here also an action was brought, which was settled for a substantial sum out of court, no one could suggest that a child of such immature age could be affected by the worry of legal negotiations, or that she was malingering.

Insomnia and other symptoms in neurasthenia.—Insomnia is sometimes a prominent symptom in neurasthenia, though in others sleep may be deeper and heavier than usual, the patient awaking tired and unrefreshed. I have had under my care a doctor in busy practice, with a good deal of nightwork, who was much annoyed by his neighbour's dog, which on several occasions barked continually during the night, keeping him awake. This started insomnia, so that the slightest noise kept him awake, and he gradually became a typical neurasthenic, being fearful of crossing the road, and in constant dread of going out of his mind. He had to give up his practice for a time, but eventually recovered completely. He exhibited a symptom which may almost be said to be characteristic of neurasthenia: an excessive flow of talk about his numerous symptoms and ailments—a symptom which has been named "logorrhœa."

Headache is a common symptom of the disease, and occurs in two types. In one the pain is situated at the back of the head, as a dull pain which may spread down the cervical spines, some of which may be acutely tender.

In the other the sensation is more one of compression, as of a heavy weight upon the top of the head; or the sensation may be as if a nail were being driven into the top of the head (the so-called *clavus hystericus*), or the top of the head may appear to be opening or shutting. A dread of crossing open spaces (*agoraphobia*), or of being shut up in a room or any place from which there is not a free exit, such as going to church, or a concert or theatre (*claustrophobia*), is sometimes a distressing symptom. I have seen the latter accompany the symptoms produced by excessive smoking—irregular, rapid heart, with the central scotoma and loss of central colour-vision that are typical of tobacco amblyopia. Another case—a lady, typically neurasthenic—could not bear to travel alone in a railway carriage for a long non-stop run, the fear of being shut in alone for so long so upsetting her that on one occasion when she was left unexpectedly alone she stopped the train by pulling the alarm signal.

In other cases, over-indulgence in drugs—alcohol, morphia, cocaine—may be the exciting cause of the appearance of neurasthenia.

Treatment of neurasthenia.—Removal of the exciting cause is necessarily the first care in the treatment of the disease, while electrical treatment is often a most useful adjunct to the more general methods of treatment. Prolonged rest is advisable in the majority of cases, some of which may best be treated by the Weir-Mitchell method of isolation from friends and letters, massage and overfeeding. General electrification by means of the faradic bath is usually the most efficacious means of ~~applying electricity~~ in these cases, the patient being immersed up to the neck in a warm bath, with two large flat electrodes applied, one to the back, the other at the feet, connected to the secondary coil of a faradic battery. Care should always be taken that the ~~current is turned~~ on quite gradually, so as to avoid all possibility of giving the patient a shock, the strength of the current being gradually increased from the minimum until the patient begins to feel it as a tingling in the toes. It should not be continued for more than ten or fifteen minutes as a rule, but the strength of the current may be slightly increased with advantage at subsequent treatments. The effect is refreshing and sedative, induces sleep, and promotes respiratory exchange and metabolism generally.

Traumatic hysterical paralysis.—For those cases of hysterical paralysis, with contracture and anæsthesia, such as may follow injuries, as already described, the faradic bath is not so suitable as the more stimulating treatment by means of the wire brush. This electrode is made in the form of a paint-brush with stiff wire bristles, and it should be dabbed on the skin, not stroked along the surface. The skin should first be wetted, as by this means the resistance of the horny layer of the epidermis is much diminished, and the strength of the current correspondingly increased. The secondary coil should be used—preferably a coil with a large number of turns of thin wire, as it is our object now to increase the cutaneous sensory effect as much as possible. The muscular contractions produced will, of course, be strong, yet the patient may feel nothing at first, though, if a sufficiently powerful battery be used (and often the full strength of the current available is required), the anæsthesia will gradually diminish in intensity and extent.

HYSTERIA

Formerly believed to be a disease peculiar to women, and to be associated with some disturbance of the uterine functions, this affection derives its name from the Greek *ὑστέρα* = womb. It is now known to occur not unfrequently in men, and in children of both sexes, and the name has therefore lost its special significance. Although the derivation of the word suggests a pathogeny of the disease which modern knowledge has shown to be quite unfounded, yet the term is clinically of use to denote a condition which is in no sense malingering, and which differs in many respects from neurasthenia. The term "functional" is often applied by some physicians to symptoms which do not appear to be dependent upon an organic basis, the word "hysteria" being avoided partly on account of its old associations of derivation, and partly from fear of making a definite decision in the diagnosis of the absence of organic disease. The term "functional" is thus often used very loosely, and is applied, on the one hand, to groups of symptoms which by others would be called hysterical, and, on the other hand, to diseases which have no known morbid anatomy, such as paralysis agitans and many epilepsies. The phenomena of hysteria may be very protean in their manifestations, and may mimic organic disease sometimes very closely—such as an hysterical joint, which may be mistaken for a tubercular joint; hysterical paraplegia, too, may closely resemble disseminated sclerosis.

The various symptoms which may be met with in hysteria are best grouped, for the purposes of convenience, under five heads:

1. Motor.
2. Sensory.
3. Special senses.
4. Visceral.
5. Psychical.

1. **Motor symptoms** may be either paralytic or spasmodic, and it is not uncommon for both weakness and rigidity to occur together in the same affected limb. One limb only may be affected (*hysterical monoplegia*), or both arm and leg of the same side may be similarly stricken (*hysterical hemiplegia*), or both lower extremities may be powerless (*hysterical paraplegia*). When the arm is affected, either alone or together with the leg, there is, as a rule,

considerable rigidity of the forearm muscles and hands, the fingers being flexed at the metacarpo-phalangeal joints, while the interphalangeal joints are rigid in extension. The fingers, at the same time, are strongly adducted together, and the position of the hand strongly resembles that seen in tetany. Hysterical spasm may be tonic or rhythmical; the latter is sometimes called hysterical chorea. It may affect some of the neck muscles and simulate spasmodic torticollis. A not uncommon form of tonic hysterical spasm or contracture is a clenching of the hand, the fingers being tightly flexed into the palm, with the thumb outside. This condition may persist, if untreated, for years, and organic shortening of the muscles and tendons may ensue, so that it may be quite impossible to straighten out the hand, even under an anæsthetic. Flaccid paralysis is sometimes met with, especially in hysterical paraplegia, though, on the other hand, the most extreme rigidity of the whole body may be present. This rigidity in cataleptic states may be so great that the whole body, from the neck downwards, with the lower extremities, may be rigid like a poker, and may be moved as one piece.

As a rule in hysterical paraplegia, even if there be rigidity of the legs, the tonic spasm does not fix the thighs to the pelvis to the same degree as is seen in organic spastic paraplegia. In the latter condition, if one leg be taken hold of by the ankle and pulled aside the other leg follows it, as though drawn by a magnet, owing to the tonic spasm of the muscles fixing the thighs to the pelvis, so that the hip-joint is scarcely moved, but the pelvis is flexed on the spine. This is a sign very characteristic of organic spastic paraplegia, and differentiates it from functional paralysis.

THE REFLEXES

The knee and ankle jerks are not, as a rule, increased in functional paralysis, though there may be a pseudo-ankle clonus, which is sometimes very difficult to distinguish from the true form. In hysterical paraplegia the plantar reflex is either flexor or absent altogether, while in true spastic paraplegia there is an extensor plantar reflex generally obtainable. The abdominal, conjunctival, and other superficial reflexes will not be altered in hysterical anæsthesia, though in organic cerebral lesions these are generally diminished on the side opposite to the lesion in the brain. In hysterical paralysis, with or without rigidity, there is almost always observable a good deal of vasomotor derangement, the periphery of the limb being generally cold, clammy, and blue.

A definite inconsistency in the strength of the affected muscles is a most useful diagnostic sign of a functional paralysis. Thus, in a case of paraplegia the patient may appear to be quite unable to extend the knee after it has been passively flexed, though, when the leg has been placed straight again and the patient is directed to keep the leg out stiff, this may be done with considerable force, the inconsistency in the available power of the extensors of the knee being a conclusive sign of a functional paralysis.

Treatment.—In the absence of any anæsthesia of the paralysed limb in hysteria, faradism must be given with caution. The wire brush should not be used, but faradism should be applied by using a moistened roller electrode, the large indifferent electrode being placed under the middle of the back. The strength of the current should be just sufficient to produce slight visible contractions of the muscles, but should not cause real pain, though as strong a sensory stimulus as can conveniently be borne is advisable. The hammer of the interruptor should, therefore, be arranged to run at a fairly high speed. It is not advisable to treat hysterical symptoms by fastening the two electrodes on to the parts to be treated, and then to turn on the current and leave it running for the fifteen or twenty minutes allotted to the treatment. The action of the faradic current in hysteria is mainly through the psychic sensory effect it produces, and the personal efforts of the operator are therefore necessary, aided at the same time by continual encouragement to the patient as to recovery. For this reason better effects are often to be obtained with a large battery, because of its greater impressiveness, than with a small one. Similarly, in the treatment of hospital patients, I always prefer to treat cases in the electrical room with large and reliable machines rather than use a smaller apparatus in the ward, where the general surroundings of the patient are too sympathetic, and the operator is handicapped by a subconscious antagonism which may be quite sufficient to determine a negative result instead of recovery.

2. **Sensory symptoms.**—Either anæsthesia or hyperæsthesia may be met with. Hyperæsthesia, when present, is generally over certain points, such as the vertebral spines, or over the groins—the so-called ovarian tenderness—though this region may be hyperæsthetic also in a man. Occasionally, though rarely, a limb may be diffusely hyperæsthetic, or the end of a stump may become acutely tender after an amputation. Anæsthesia may be complete or partial, and may involve one half of the body (hemianæsthesia), or only the paralysed limb may be anæsthetic. Babinski has recently recorded his opinion that the hemianæsthesia so often demonstrated in hysteria is always the result of unconscious suggestion to the patient by the physician's methods of testing. If, he says, special care be taken in the method of testing the anæsthesia in a patient who has not previously been examined, hemianæsthesia is never found.

That this may be true of a certain number of cases, I am willing to grant, but I am convinced that the symptom is as genuine as any other hysterical sign, and I have known patients who have themselves noticed, before ever being tested, that they had lost feeling on one side of the body, usually the left side, and that their hearing and eyesight on that side were also diminished in acuity.

A not uncommon form is "stocking-and-glove" anæsthesia, the hand and leg being anæsthetic up to a circular line drawn round the wrist and knee respectively. Patchy areas of loss to touch or pain may also be found on the trunk irrespective of any motor paralysis. The hyperæsthetic areas above alluded to may act as hysterogenetic zones; that is to say, when pressed upon, the patient may be thrown into hysterical convulsions or exhibit other hysterical psychical phenomena. Headache, if present, is usually vertical, sometimes causing a sensation as of the head opening and shutting, or as if a nail were being driven into it (*clavus hystericus*).

3. The **special senses** may be affected by hyperæsthesia or anæsthesia. The eyes may be excessively sensitive to light, or one eye may be temporarily amblyopic. Complete loss of perception of light in both eyes, or *amaurosis*, seldom occurs. When there is hemianæsthesia, the eye on that side may be amblyopic, with a greatly contracted field and loss of colour-sense, and smell, taste, and hearing on that side may be similarly defective. Rarely the visual fields of both eyes may be extremely contracted: the so-called *pin-point fields* of hysteria.

A sensation of a lump rising in the throat (*globus hystericus*) is due to irregular contractions of the œsophageal walls or pharyngeal muscles. Due to a similar cause are *phantom tumour*, and the so-called *hysterical peritonitis*, both caused by irregular contractions of the abdominal muscles and intestinal walls.

Joint disease may be simulated, the best-known form being the hysterical hip, in which the general symptoms may simulate hip-joint disease.

The speech may be affected, *hysterical aphonia* being not at all infrequent. The voice is reduced to a mere whisper, owing to inability to adduct the vocal cords in phonation.

Seen with the laryngoscope, the cords appear widely abducted, very slight movements of adduction occurring on attempting to phonate. In spite of this apparent paralysis of adduction, perfect power of coughing is retained, the full explosive expiratory effort necessary for this being proof that adduction of the cords has taken place in the natural manner. This inconsistency in the power of the adductors is the best evidence of such an aphonia being functional. The tolerance of laryngeal examination that is shown by these patients is often remarkable, the pharynx and larynx often being partially anæsthetic.

Mutism, or hysterical aphasia, is occasionally met with. There is apparent complete inability to articulate a single word, although the power of understanding everything that is said or written remains unimpaired. There is a considerable likelihood of these cases being diagnosed wrongly as motor aphasia, and it is very important to distinguish them clearly from the latter, as the treatment of the two conditions differs widely. Hysterical mutism is usually found in young women, and is often produced by some mental shock, emotion, or worry.

Spasmodic cough, of a vibrant, harsh tone, unaccompanied by any expectoration, is also not very uncommon. In young girls this hysterical cough has been named "*cynobex hebetis*," or the barking cough of puberty, owing to a supposed resemblance in sound to the bark of a dog.

4. **Visceral symptoms.**—*Anorexia*, or complete loss of appetite, may reduce the patient to skin and bone. *Vomiting*, often supposed for months to be due to some organic cause such as gastric ulcer, may be accompanied by small quantities of blood, bright red, due to gum-sucking or some other semi-voluntary cause, which may easily be mistaken for hæmatemesis. As a rule, these patients are not much emaciated, and if the vomiting and false hæmatemesis have continued for many months, as in a case I

have recently had under observation, the well-nourished condition and ruddy lips of the patient may at once give a clue to the hysterical nature of the case. Such vomiting may be accompanied by *anuria*, and the ejected material may even contain urea. It is difficult to understand how such anuria can continue for days, or even weeks, with a daily average of not more than two or three ounces of urine being passed, without serious constitutional symptoms arising, yet several most carefully watched cases have been recorded. *Ballooning of the intestines* from arrest of peristalsis and accumulation of gas, with obstinate constipation, may occur. This protuberance of the abdomen was one of the most obvious symptoms in the epidemics of hysterical dancing mania that occurred in the late middle ages.

Dyspnœa, with excessive frequency of respirations, amounting to as much as 90 to 100 in the minute, may persist for several hours, or even for a few days. It is the only condition in which the rate of the respirations ever exceeds the pulse-rate, with the possible exception of asthma. *Hiccough* may occur as a functional symptom, though usually it is met with in profoundly debilitated states. There is a close nervous connection between the lower end of the intestine and the respiratory centre, and hiccough is not infrequent after operations on the rectum, especially for cancer. It may last for several days, when it is likely to cause considerable exhaustion. It may occur in the course of other nervous diseases, and I have seen it severe in hemiplegia with weak heart and emotional attacks, in progressive muscular atrophy, in pseudohypertrophic muscular paralysis, etc.

Palpitation and *tachycardia* are also occasionally hysterical in origin, and there may for a time be some difficulty in distinguishing the neurotic form of tachycardia from the larval form of Graves's disease, in which there is cardiac disturbance without the usual ocular or thyroid symptoms. In the latter the increased rate of the heart is more or less constant, and persists even during sleep, though to a less degree. In neurotic tachycardia the increased rate will be paroxysmal, and will cease entirely during sleep. Throbbing of the abdominal aorta is sometimes excessive, and may occasion a good deal of discomfort and anxiety to the patient. There ought to be no difficulty in diagnosing the condition, yet I have several times known a wrong diagnosis of aneurysm to be made.

Pyrexia is hard to understand as an hysterical symptom, and yet undoubted instances have been recorded, in some of which the extraordinary range of 110° and 117° have been unaccompanied by any grave constitutional symptoms, and have been recovered from. Such occurrences of hyperpyrexia should always suggest fraud, and in the majority of instances this has been detected, such means as rubbing the bulb of the thermometer on the sheet or blanket, or heating it before the fire or in a poultice, being most commonly employed. However, as already said, a few cases have been carefully tested and fraud excluded:

5. **Psychical symptoms** met with in hysteria include *convulsions*, which may usually be distinguished from epileptic fits by their longer duration, persistent struggling, talking, and attitudinising, without loss of the conjunctival or pupil reflexes. *Double consciousness*—a curious mental state in which the patient suddenly passes from one personality to another totally different, thus living two alternate different existences, each, as a rule, totally unconscious of the other—may alternate with sleep-walking or even insanity.

Treatment of hysteria.—The treatment of the sensory, visceral, and psychical symptoms of hysteria will vary with the age and sex of the patient, as well as with the form and character of the symptoms present. Hysterical *convulsions* may often be arrested by a strong painful stimulus, especially by steady pressure upon the supraorbital nerve at the point where it crosses the eyebrow. Should a cataleptic state supervene, strong faradism, applied with a wire brush, will be the best treatment. To get the best results, the skin should be wetted, and the wire brush dabbed, not stroked, upon the skin. Hysterical *anæsthesia* may often be cured in the same way by faradism, though there is always great liability to relapse. *Hyperæsthesia* must be more delicately handled, for if drastic measures be applied, as strong faradism to the hypersensitive areas, the patient may even be thrown into hysteroid convulsions, or such a state of terror and resentment may be aroused that it will be difficult to exercise any further control over him or her. In such a case it is often wise to commence treatment by placing the hyperæsthetic limb, if such is the affected area, in the faradic bath. Such hyperæsthesia is not unfrequently met with on the stump of an amputated limb, a condition which may easily be mistaken for painful neuroma. In distinguishing these two diseases, it should be remembered that painful neuromata occur only after there has been suppuration, so that if the wound after the operation healed by first intention, then it is highly probable that the hyperæsthesia is hysterical. Again, in the latter case the excessive tenderness is mainly superficial, often the lightest touch appearing to cause great distress; while in true painful neuroma the pain is not brought out unless there is a certain amount of pressure on the part, and it is limited to the neighbourhood of the scar. After applying weak faradism by means of the faradic bath, the sensitive area should be gently rubbed with a roller electrode and a gradually increasing strength of current turned on. At the same time, while applying the treatment it is important to encourage the patient with the assurance that the trouble will soon be cured and disappear, because of the enormous influence that reflex psychical impressions have upon the nervous system in hysterical patients.

Some hysterical cases respond better to treatment by sparks from the static machine or by high frequency currents. It is difficult to say which form of current will serve the better in any case, but the choice should be between these three : faradism, with or without the wire brush ; sparks from the static machine ; or the high frequency treatment. Galvanism and sinusoidal currents are of less value.

Pathology.—The pathology of hysteria must be understood if the best results are to be attained in its treatment. There is usually a strong hereditary taint of neurosis—epilepsy, insanity, or the like ; and there is frequently an element of fraud or malingering superadded to undoubted hysterical symptoms. The condition may lie latent, and only be brought out by some severe illness, influenza, or bodily or mental shock. The symptoms are due to a temporary loss of control of certain of the higher centres over lower ones, or else to an automatic and abnormal restraining influence of higher on lower centres, an auto-inhibition. The excessive emotional attacks and hysterical fits will be instances of the former condition, while hysterical paralyses and anæsthesias illustrate the latter. For some years I have taught, following Bernheim, of Nancy, that the psychical auto-inhibition which produces hysterical paralysis and anæsthesia is precisely comparable to the hypnotic state.

These disorders of function are not accompanied by any gross or microscopical change in the nerve cells, nor is it probable that there is any nutritional change at first, though this may occur later if the morbid hysterical state remains uncured. At first, however, the hysterical paralysis of motion, sensation, or special sense may be instantaneously cured by the effect of a reflex sensory stimulus. This may be conveyed by the suggestion of psychical impressions, as the religious enthusiasm evoked at Lourdes, or a sudden mental shock or fright, such as of fire. The longer that hysterical paralysis, spasm, or anæsthesia remains uncured, the more difficult is it to remove by treatment, and the longer it takes to do so. It is therefore important that the treatment should be energetic, though not necessarily very painful, and efforts should be made to impress the patient's attention and respect for the apparatus employed, for the cure is produced by reflexly affecting the higher psychical centres by means of stimuli applied to the skin or the other special senses. In this way the excitability of these cortical centres is altered, and the inhibitory effect on lower centres taken off.

As an illustration of what is meant by the sudden removal of this process of auto-inhibition, the effect of suggestion in hysterical unilateral amblyopia and loss of colour-vision may be cited. The acuity of vision in one eye is then much reduced, and, though this is generally unknown to the patient, there is loss of colour-vision in this eye, though colours are normally perceived by the other. On placing trial frames with two prisms, one base upwards, the other base downwards, before the eyes, vertical diplopia is produced, and it will then be found that, if the patient is made to read the test types with both eyes open, the upper and lower images will be equally well read, corresponding to the previously ascertained acuity of vision of the good eye. Coloured objects will also be seen equally well in the upper and lower images, though if the good eye be now covered it will be found that the colour instantaneously fades out of the remaining image, and the sight of that eye becomes amblyopic, as before, as soon as the patient's attention is directed to it. Thus an inconsistency in the vision of that eye has been shown, proving the disability to be of a functional nature. Malingering is excluded, for the reason that the patient is nearly always unaware of the colour-loss in the amblyopic eye, and if asked whether colours are recognised as well as usual the reply is in the affirmative, as is indeed the case with both eyes open, because the colours are then seen by the good eye as well.

The visual field is often much contracted in hysteria, and, if perimeter charts are taken, it will be found that the field becomes more and more contracted as the test is carried on, a helical contraction. In a few cases the fields of both eyes are so contracted that they do not extend more than five degrees around the fixation point, the so-called pin-point fields of hysteria. A similar bilateral contraction of the fields may be met with in cases of double hemianopia, in which, after the lapse of some months, a small area of central vision returns around the fixation point. Great contraction of the fields may also be met with in retinitis pigmentosa and in choroiditis. True hemianopia does not occur in hysteria, but it may be simulated by an irregular contraction of the fields in which the contraction is much greater on one side than the other. In one such case I was able to produce complete blindness by suggesting to the patient that she should lose her sight on the other side as well. On the next morning she woke up quite blind and unable to see light, being much distressed thereat, and crying and sobbing all day on account of her loss of sight, which she supposed was permanent. Vision was restored to her that evening by the process of suggestion, aided by passing weak galvanic shocks through her eyes, and telling her that the current was being gradually increased, and that the flashes of light which she saw as the result of the retinal stimulation were becoming brighter and brighter, though as a matter of fact the current was not being altered.

CONVULSIVE TIC

Facial spasm may be due to a partial lesion of the face centre in the motor cortex, or of the pons near the facial nucleus, or a lesion of the nerve from pressure as in cerebellar tumour, or from a partially recovered facial neuritis. In neither of these is faradism of any service, and the term "tic" does not properly apply to them. Convulsive tic of the face should be distinguished from "tic douloureux," which is its sensory equivalent. Convulsive tic is a functional spasm which may affect the face or other groups of muscles, and does not depend upon any organic lesion, but may be produced reflexly by cold, or by emotion, unconscious mimicry, and the like. A slight form of the affection is familiar to most of us in the form of a twittering of the muscles of the eyelids, known as "live blood" or "bird in the eye." This is especially apt to come on if the individual is run down in health, or worn out after prolonged mental stress. It may continue for hours at a time, and even keep the patient awake most of the night.

Treatment.—In such a severe attack the spasm may generally be arrested at once by the application of faradism. Two circular pad electrodes, about an inch in diameter, should be employed, one placed over each eye, and a weak current turned on, using rapid interruptions. The current should be sufficiently strong to be distinctly felt, but not to cause real pain. Five minutes' treatment usually suffices. Convulsive facial tic is not uncommonly seen in boys, and I have several times seen it cured by faradic treatment carried out as above. Its effect is produced through its strong sensory stimulus acting reflexly as a sedative on the hyperexcitable motor centres. As Gowers* says, " . . . Indeed, it is important to remember that strong sensory impulses from the seat of the spasm have more power than any other agency to raise local resistance and arrest over-action. This opposition of reflex influences is a familiar fact." Yet, on the same page, he deprecates the use of electricity in the treatment, and says that only a weak voltaic current should be employed, with no interruptions of the current. This form of treatment would have the least sensory effect, and is really contrary to his advice quoted above.

---

* "Manual of Diseases of Nervous System," 2nd Edtn., II., 258.

French authors use the term " tic " in a wider sense than is common amongst English writers, classifying under this head many chronic forms of muscular spasm combined with ataxy of the limbs, as well as of the head, facial muscles, and articulation. Electrical treatment does not seem of any avail in these cases. In *spasmodic torticollis* faradism is sometimes of service. Galvanism is the form of electrical treatment usually ordered ; but, in my experience, faradism has been of at least equal service, which is, however, not saying much. Sometimes faradism of the muscles on the opposite side to those affected by the spasm has been said to relieve, and, undoubtedly, systematic exercises may in certain cases be of the greatest service. In a severe case of spasmodic torticollis, according to my experience, neurectomy is the only treatment likely to cure the condition. In addition to excision of a piece of the spinal accessory nerve on the side of the affected sterno-mastoid, it is generally advisable to divide the posterior branches of the upper four cervical nerves on the opposite side (Keen's operation). Even then a certain amount of spasm may remain in the splenius or trachelo-mastoid or complexus of one side, which must then be treated by careful massage, and by the daily performance of head exercises.

NEURALGIAS

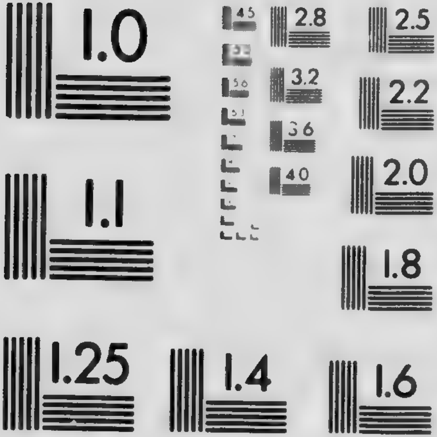
During the inflammatory stage of neuritis, faradism is of no use in the treatment ; on the contrary, its employment will aggravate the pain. After the inflammatory stage has subsided, however, pain in many cases persists, due to one of two causes. In some cases, for example **sciatic neuritis,** the perineuritic inflammation of the sheath of the nerve may give rise to adhesions, which remain after the inflammation has subsided, and the dragging of these adhesions upon the sheath of the nerve may keep up the pain almost indefinitely. This is the class of case that does well by stretching the nerve with Swedish massage and forcible movements. Care must be taken not to apply such drastic treatment during the stage of acute or subacute inflammation of the nerve, or the severity of the symptoms will probably be much increased. I have known many cases of sciatica made much worse by the too early application of massage.

The other cause of persistence of the pain after subsidence of the primary perineuritic inflammation of the sheath is a neuralgia limited to the distribution of the affected nerve. In these cases the pain is not due to adhesions, and there is no diffuse tenderness along the course of the nerve, nor does traction on the nerve by flexing the hip, keeping the knee extended, produce the pain so characteristic of the first two varieties of sciatica. In this form of sciatica either faradism or galvanism may be of the greatest benefit, and I have known a severe case which followed typhoid fever, and had defied treatment by rest in bed for two months, disappear completely after two weeks' treatment with both currents. The faradism is best applied by a roller electrode rubbed along the back of the thigh and buttock, with a large pad as the indifferent electrode bent round the calf. The strength of the current should be sufficient to produce weak contractions of the muscles, but not to induce pain. The treatment of subacute and chronic sciatic neuritis by means of galvanism will be described in Chapter V.

Neuralgic pains may be met with in the limbs or trunk along the distribution of many other nerves, but it is especially in the head that neuralgia is apt to be severe and frequent. Occasionally it occurs at the back of the head, along the course of the great occipital nerve; but it is most usually met with in the distribution of the trigeminal, or fifth cranial nerve. The slighter forms are

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc

1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

limited to a portion of the face or front of the head, as the forehead, eyebrow, side of the nose, or gums.

The term "neuralgia" as used here is meant to include only nerve pains which have no organic basis, while those which are dependent upon actual lesion of nerve fibres are to be described as symptoms of neuritis. When pains due to organic disease, however, become chronic, such as those of chronic rheumatism or tabes dorsalis, they are frequently spoken of as "neuralgic."

Neuralgic pains in the trunk or limbs must be carefully investigated before it is decided that they are a true neuralgia, and not due to a chronic rheumatic muscular fibrositis, rheumatoid arthritis, neuritis, or some disease of the spine such as caries or tumour, or of the spinal cord such as tabes dorsalis. Again, chronic pains suggestive of neuralgia, though really symptomatic of chronic Bright's disease or diabetes, may easily mislead the unwary—a mistake which a routine examination of the pulse and urine would prevent. Often the pulse will give a valuable clue to the elucidation of vague pains and other symptoms which may otherwise be attributed to neuralgia or to hysteria. Gently rolling the pulse under the finger will detect the hard artery with thick walls, which is an indication of arterio-sclerosis with its attendant train of evils, either present or threatening in the form of chronic Bright's disease, gout, asthma and chronic bronchitis, cardiac hypertrophy, angina pectoris, etc. In any of these complications of arterio-sclerosis, neuralgic pains in the limbs or head are a not unfrequent symptom. Needless to say, faradism is likely to prove a failure if used in the symptomatic treatment of these diseases.

An exception may, however, be made in the case of rheumatic myalgia such as **lumbago**, or the sharp muscular pains accompanied by stiffness around the shoulder, hip or neck. For this form of muscular rheumatism faradism, given with a roller electrode as strong as can conveniently be borne, may have an immediate effect in diminishing or even abolishing the pain and stiffness. The best results will be obtained if combined faradism and galvanism are given at the same time with the roller electrode, the battery being so arranged that the roller is the anode, and a current of 7 to 8 ma. of constant current used in addition to the faradism.

Sometimes after an attack of **pleurisy** a severe persistent neuralgia may remain in the side, possibly associated with the presence of pleuritic adhesions. I have seen the greatest relief given in several of such cases by the use of the roller electrode and faradism, and the rapid cure and disappearance of pain which had remained for months in despite of other forms of medical treatment.

Severe neuralgic pains in the head or face are apt to be confounded with other causes of headache. Thus the severe headache of cerebral tumour, when paroxysmal, is liable to be mistaken for neuralgia in the early stages. An alveolar abscess, or suppuration in the antrum of Highmore, or in the frontal sinuses, may also be overlooked and the pain ascribed to neuralgia. Dental neuralgia is a very common form of faceache. The pain is a true reflex neuralgic pain, though it is started by an irritation or actual inflammation of a peripheral twig of the same nerve. Faradism is not, however, a good mode of treatment of such cases, as there are better ways open to us of relieving the pain. In true dental neuralgia, in which there is not actual continuous irritation of a twig of the nerve by caries of a tooth going on, a stiff dose of fifteen grains of quinine often relieves within an hour, and may permanently cure the trouble. Electricity is sometimes of great use in the treatment of severe rheumatic neuralgia of the face, but in the form of galvanism, not faradism. Similarly the severe form of facial neuralgia known as trigeminal neuralgia or tic douloureux is not amenable to faradism.

NEURITIS

A frequent instance of a neuritis due to a locally acting cause is the common form of *facial paralysis* or Bell's palsy, due to exposure to chill. The facial being a motor nerve only, with the exception of the gustatory and secretory fibres that run in the chorda tympani, the paralysis is not preceded or accompanied by pain or any sensory symptoms. Although at first the paralysis may be complete and the angle of the mouth drawn over to the opposite side, with inability to close the eye, yet both the nerve and muscle will respond to faradism, and the facial muscles will not lose their faradic excitability for a week to ten days. In the slighter cases, in which the nerve fibres are scarcely more than pressed on by inflammatory exudation, the nerve does not lose its faradic excitability altogether, but the muscular contractions will be somewhat diminished to faradism, with at the same time slight hyperexcitability to galvanism, equally to kathode and anode, the anodal closing contraction being the more sluggish of the two. This is known as a partial form of the reaction of degeneration.

Faradism should never be used in the treatment of facial paralysis in any of its stages, and it is useful only in the diagnosis of the severity of the lesion, and therefore in the prognosis. After the paralysis of the face has lasted two or three days, an alteration of the electrical excitability of the facial nerve can usually be detected. At first there is often a short period during which the nerve is hyperexcitable both to faradism and to galvanism, so that when the testing electrode is placed upon the exit of the nerve close to the mastoid the muscular contractions of the paralysed side of the face will be made evident with a weaker current than is necessary to provoke similar contractions of the facial muscles on the sound side, when the testing electrode is placed in the corresponding position behind the other mastoid. This wave of hyperexcitability is followed by diminished excitability of the nerve to both currents, and in severe cases by total loss of conduction power of the nerve to both currents. The condition is known as the reaction of degeneration of the nerve, and is to be distinguished from the reaction of degeneration of the muscles which develops at the same time and is different in type. (*See* p. 129.)

Although the amount of diminution of faradic excitability of the muscles may be taken as a measure of the severity of the lesion of the nerve about ten days after the onset of the paralysis, yet return of faradic excitability is by no means the first symptom of commencing recovery. In cases of facial paralysis the first sign of commencing recovery is always the return of tonic contraction of the facial muscles, so that the face becomes straighter again and the deformity is less marked, although the paralysis for voluntary movement is still as complete as before. Usually return of voluntary power in the muscles commences some weeks before the return of faradic excitability.

Blepharospasm is a reflex spasmodic contraction of the orbiculares palpebrarum of the two eyes, and is due generally to irritation of terminal branches of the fifth nerve, ending in the ocular conjunctiva or cornea, either from conjunctivitis, or as the result of a foreign body or corneal ulcer. It is usually associated with photophobia, but it is not only due to the irritant action of light falling upon the eye, as it may be continued when the patient is placed in a dark room, or it may be present in a blind eye. Reflex blepharospasm may also be produced by irritation of other branches of the fifth nerve, as by carious teeth; or the spasmodic closure of the lids may be associated with photophobia set up by irritation of the retina from the action of a very bright light. "Snow-blindness," and the similar condition that may follow exposure to the action of a bright arc lamp or the X-rays, is generally due to an acute conjunctivitis. Exposure of the retina to the sun's rays directly, as by using an insufficiently-smoked glass to observe a solar eclipse, may, by damaging the retina, produce a permanent blindness, associated with photophobia, but no conjunctivitis.

Blepharospasm may be partial and affect one eye only, in cases where there is a long-continued stubborn conjunctivitis of that eye. The condition then simulates *ptosis*, since the eyelid is partially dropped over the eye; but this reflex contracture of the orbicularis may be distinguished from ptosis by the fact that the eyebrow on that side hangs lower instead of higher, as it would do in a case of weakness of the levator palpebræ. In true ptosis the eyebrow is permanently raised by the tonic contraction of the frontalis on that side, causing wrinkling of the forehead in the unconscious effort to aid the weak levator palpebræ in raising the upper lid; whereas in the case of blepharospasm simulating ptosis, the eyebrow is pulled down by the contraction of the orbicularis, the forehead remaining smooth. This form of blepharospasm is sometimes spoken of as "ptose volontaire." Other causes of this form of ptosis are: (1) diplopia from slight strabismus, and (2) paralytic dilatation of the pupil on the same side. True ptosis is always associated with wrinkling of the forehead on that side, unless there is paralysis of the frontalis muscle also. In myasthenia gravis there is commonly bilateral ptosis with smooth forehead, due to the associated weakness of the frontales, and this appearance is so distinctive of this rare disease that the disease may often be recognised at a glance by its means.

Hysterical blepharospasm may occur as part of a convulsive tic (*see* p. 74), or it may persist after the conjunctivitis or other reflex irritant cause which produced the blepharospasm has been entirely cured. In the treatment of blepharospasm it is clearly necessary to search carefully for any irritant reflex cause, such as a slight conjunctivitis, corneal ulcer, or foreign body. In the absence of what may be thought sufficient cause of this nature, the diagnosis of functional blepharospasm may be made, and in this group of cases faradism to the eyelids may arrest the spasm completely. An instillation of cocaine into the eye may also be successful, either alone or as supplementary to the faradic treatment. Circular pad electrodes should be used, one being placed over each eye, if both are affected. The current applied should not be strong enough to cause pain, but just enough to cause weak contractions of the facial muscles.

HEMIPLEGIA

Hemiplegia may be benefited to a certain extent by faradic treatment when it is due to an organic lesion. This has a stimulating effect, and will aid in preventing the wasting of the muscles that commonly ensues; and at the same time it improves the sensibility to tactile and other sensations, and the stereognostic sense or power of localising and appreciating the various forms and weights of objects. Unless the anæsthesia is profound, as may occur in some lesions at the back of the internal capsule, or the dorsal tegmental portion of the crus or pons, the treatment is best applied by means of the roller electrode to each limb separately, the indifferent electrode being applied to the middle of the spine. In the majority of cases the anæsthesia is of the type known as "cerebral," in which the most paralysed part is the most anæsthetic; that is to say, the foot and hand are more paralysed and also more anæsthetic than the ankle and wrist, and these latter than the knee and elbow. In lesions of the posterior portion of the internal capsule, the so-called "sensory crossway" of Charcot, or, again, of the tegmental region of the crus or pons involving the fibres of the fillet, then the anæsthesia produced is different in type to that just described, involving one half of the body, face, neck, trunk, and limbs in about equal degree. Occasionally, though rarely, the anæsthesia in these cases is so deep that hard pinches or deep pricks of the skin on the affected side may be practically unfelt ; and I have known one such case, due to a thrombosis in the dorsal region of the pons, in which the motor disturbance was transient only and completely recovered from, but the hemianæsthesia was so deep and permanent that when the man was lying in bed upon the affected side he was unable to feel the bed, and said that it felt to him as if he were suspended in the air with the bedclothes hung over him. Anæsthesia of so profound a degree as this may be improved by using the wire brush electrode, the skin being previously wetted, and the brush dabbed upon the skin, not stroked along it.

Though faradism used in this way is occasionally very useful in the improvement of the anæsthesia and the motor weakness in cases of partial paralysis down one side, it is of no benefit in old standing cases in which the late rigidity that is associated with sclerosis of the motor fibres in the pyramidal tracts has set in. Much the same applies to other spastic conditions, as disseminated sclerosis, ataxic paraplegia, combined sclerosis, lateral sclerosis, and myelitis. When spasticity is well-marked, the limbs being rigid in adductor and extensor spasm, with knee and ankle clonus and extensor plantar reflex present, then faradism is contra-indicated in the treatment.

DISSEMINATED SCLEROSIS

In the early stages of the disease faradism may be of the greatest service in aiding the disappearance of the paralysis. In this curious disease the mode of onset is often practically sudden, or very acute, with considerable loss of power in one or both legs, as a rule. Sometimes the motor weakness is hemiplegic in distribution, or ocular paralyses, causing diplopia, may be the first symptom, or sudden partial blindness in one eye, or aphonia, or sphincter trouble. Owing to this multiplicity of modes of onset of the disease, and the fact that it usually attacks young females under the age of thirty, a diagnosis of hysteria is not uncommonly made instead of organic disease of the central nervous system. Some, indeed a considerable number, of cases of disseminated sclerosis resemble hysterical paralysis still more, owing to the variability in the progress of the symptoms, which often improve to a considerable extent—indeed, almost as far as actual recovery. If a diagnosis of hysteria has been previously made, it will appear to be considerably strengthened by the more or less rapid recovery which then ensues. This type of disseminated sclerosis always relapses, however, sooner or later, and recovery is never quite perfect; that is to say, the patient is always left a little weaker after each relapse, never quite reaching the previous state of health. Other cases of the disease develop slowly and steadily, and these are more likely to exhibit the classical symptoms of incoordination of the arms, with the characteristic intention tremors, scanning speech, and nystagmus.

The cases that are difficult to recognise as disseminated sclerosis are those of the so-called paraplegic type, in which there has been more or less rapid loss of power in the legs, with sphincter trouble, increased deep reflexes, and extensor plantar reflex, but without the intention tremors, nystagmus, and syllabic utterance. Disseminated sclerosis is essentially a cerebro-spinal disease, and in this latter type the spinal symptoms are in evidence, but the cerebral and bulbar signs are in abeyance. Often it is impossible to be certain of the diagnosis, but a chronic paraplegia in a young woman, with little or no anæsthesia, but with increased deep reflexes, extensor plantar reflex, and sphincter involvement, will always be very suggestive of disseminated sclerosis, and the diagnosis will become almost certain if, in addition, there are any signs of cerebral or bulbar involvement such as incoordination of the arms, tremor of the head on sitting up, staccato speech, nystagmus, diplopia, or optic atrophy.

It is in the relapsing type of disseminated or insular sclerosis that electrical treatment is often of considerable service. Many of these patients are of neurotic disposition, and a modified form of Weir-Mitchell treatment will often succeed best. Massage, faradism, with good feeding, plenty of milk, and rest in bed for three or four weeks, will be the best lines to proceed upon ; and though it is undoubtedly true that in a number of cases little or no benefit may ensue, yet, at any rate, the treatment cannot do any harm, and may occasionally be followed by an immense amount of improvement. The faradism should be applied by the roller electrode, with the indifferent electrode applied as a large pad over the cervical spine. No strong measures should be adopted in the shape of powerful currents, as may occasionally be done with advantage in hysteria, the current employed being of only sufficient strength to cause weak contractions of the muscles. This should be given daily before the massage treatment, for twenty minutes.

TABES DORSALIS

In tabes dorsalis, again, faradic treatment will sometimes assist in diminishing the anæsthesia and sensation of numbness in the legs, and the ataxy may be also at the same time correspondingly benefited. Very occasionally a considerable functional element may be superadded to the organic disease present, and I have seen a man suffering from well-marked tabes, with partial optic atrophy, who walked with typical hysterical shuffling of the feet, and whose skin was almost completely analgesic, and the visual fields extremely contracted. Energetic treatment with faradism in his case with the wire brush soon dissipated the greater part of the anæsthesia and analgesia, whilst his gait and vision improved very much. Not much is to be hoped for, however, from electrical treatment in the large majority of cases of tabes, and the ataxy is much better treated with re-education of the movements by means of regular exercises on specially devised instruments, such as Frenkel's steps. The lightning pains are not, in my experience, benefited at all by faradism, or, indeed, by any other form of electrical treatment. This is, perhaps, the most difficult of all the symptoms of tabes to relieve. I have once seen the pains practically cured by a course of heat baths, and in two or three instances I have seen the pains diminish very much, at the same time as marked improvement took place in the ataxy and other symptoms of the disease, while the patient was being energetically treated by mercury. In early cases, especially if the symptoms have developed at all acutely, I generally treat with inunction of the oleate of mercury, 10 per cent., made up with lanolin, and at the same time give the biniodide of mercury by the mouth. If attention is paid to the gums and teeth, it is remarkable how long the majority of the patients can continue this treatment without showing any signs of mercurialism.

GRAVES'S DISEASE

This disease, also known as Basedow's disease in Germany, and as exophthalmic goitre, has nearly always a moderate enlargement of the thyroid gland as one of the prominent symptoms. This goitre differs from the ordinary form of bronchocele in that the gland is in an active rather than passive state, and its cell protoplasm stains brightly, with numerous granules, indicating a state of active functioning of the glandular elements. The thyroid, moreover, is flushed with blood, with all its arteries dilated, so that on auscultation over the swelling a systolic bruit can be nearly always heard. Although Graves's disease is largely a neurosis, yet many of its symptoms suggest an absorption of an excessive amount of thyroid secretion, and for this reason many forms of treatment, besides excision of a portion of the gland, have been directed towards diminishing the activity of the gland. One of these means is the application of faradism to the goitre. It is best done by using a small flat electrode fastened in position on the back of the neck, and a circular pad electrode to be moved slowly over the surface of the swelling. This should be applied for twenty minutes daily, and the patient can usually be taught to do it for herself.

It is a good plan in all cases of exophthalmic goitre in which the symptoms are at all marked to insist on an hour's rest in a recumbent posture before lunch, and the faradic treatment can be advantageously applied at that time. It should be persisted in for several weeks, and it is sometimes followed by considerable improvement. The effect of the faradic current upon the gland appears to be to cause vascular constriction, and therefore shrinking of the goitre, and at the same time the tachycardia and nervousness may improve and the patient feel generally better. It is necessary to remember the importance of rest in the treatment of this somewhat stubborn disease, as unless the patient's daily life be so arranged as to avoid all physical hurry and mental worry, no medicinal or other means of treatment will be of the slightest benefit. Strict rules must be laid down for the patient's guidance, especially as to the amount of exercise allowed, which should be little, and taken at a slow pace. (*See also* Chapter VII., p. 230.)

LEUKÆMIA

Leucocythæmia may be similarly treated by the application of faradism over the enlarged spleen daily for a period of several weeks. A flat electrode should be applied by close pressure over the posterior pole of the spleen, and a smaller flat electrode pressed over the anterior portion. Using a weak current that will just cause slight contractions of the muscles of the thenar eminence, and letting it run thus for about twenty minutes daily, may be followed by immense improvement. In a recent case in which I used this method the number of white cells per cubic millimetre of blood fell in four weeks from over 200,000 to less than 10,000, or the normal amount. It is true that the patient was at the same time taking moderately large doses of liquor arsenicalis, but since this drug treatment had been previously administered for several weeks without much improvement it certainly seems fair to ascribe some at least of the subsequent rapid disappearance of the leucocytosis to the additional electrical treatment. (*See* pp. 234 and 346.)

HEADACHE

When it is of the neuralgic type, and due to excitement or other form of nervous overstrain, headache may occasionally be relieved like magic by the use of faradism. It is especially when the pain is frontal that this form of treatment is capable of giving relief, though if the headache is of the throbbing variety and made much worse by slight stooping, faradism is contra-indicated. When the pain is dull and aching across the forehead, such as may result from straining the eyes and the attention at a picture gallery, the treatment is best applied by two soft circular pad electrodes placed one on each temple, though in some cases it answers better to place one electrode at the root of the nose and the other at the back of the head below the occipital protuberance. The patient should always be either lying on a couch or sitting back in a comfortable chair when the treatment is being applied, with the head slightly thrown back. Five minutes only of the treatment should be given at a time, but it may be repeated after an interval of ten minutes, if necessary.

Another form of functional headache which may be relieved by faradism is the neurasthenic type. In this variety, the pain is frequently a dull weight on the top of the head, or the top of the head may seem to be lifting off as though the head were bursting. Or the pain may resemble the sensation of a nail being hammered into the top of the head (the so-called "clavus hystericus"). A typical instance of this form of headache occurred in a baker, *æt.* forty-two, who was sent up from the country on account of the constant pain, and sensations of nervousness and inability to work. He slept heavily, as is common in these cases, yet felt no better and unrefreshed in the morning. He complained of a constant sensation at the top of the head as though it "were all alive," and as though his head were going to burst. As he had been in this condition for twelve months he was becoming alarmed about himself. Cross-questioning elicited the fact that about a month before his symptoms commenced he lost a favourite daughter from diphtheria, and the mere reference to the subject was sufficient to make him partially lose control over his emotions. He was evidently run down and in a nervous state, the tongue slightly furred, and bowels constipated. Faradism was applied by means of two circular pad electrodes, one to the back of the neck and the other over the vertex, a gentle current being gradually turned on and increased to the point when it began to be strongly felt, but not painful. Stroking the electrode over the vertex, the suggestion was then put strongly before the man that he was now going to get better, and that he would soon be cured; that he would wake up refreshed, bright, and happy in the morning; that his nervousness and headache would disappear; and that he would soon be able to return to work. These suggestions were constantly repeated to the patient while the faradism was being applied, care being taken that the man's attention was not distracted by anything else, and he was told to give his whole attention to all that was being said to him and done for him.

Faradism was thus used merely as a means to the treatment by suggestion, and though no hypnotic state was produced, yet the constant reiteration of the suggestion that he was now going to get better so influenced his subliminal consciousness that the morbid sensations from which he had suffered for so many months soon disappeared and he recovered perfectly and returned to his work. This element of treatment by suggestion is a most important one in the treatment of all functional or neurasthenic symptoms, and the faradic battery, with its strange noise, and unknown powers, may thus be used as an important adjuvant in producing the receptive state of mind in the patient necessary for the implantation of suggestions as to his speedy recovery.

DILATED STOMACH

In the atonic form of gastrectasis faradic treatment may be of very considerable service, but before deciding upon the use of faradism in a case of dilated stomach it is important to exclude the existence of any obstruction at the pylorus or in the first part of the duodenum as the cause of the dilatation. Obstructive dilatation of the stomach is most commonly due to one of two causes: (1) cicatricial contraction of the pyloric end of the stomach from peptic ulceration, and (2) carcinoma of the pylorus. Less common causes of obstruction will be stricture of the pylorus or first part of the duodenum from adhesions around the liver or gall bladder or from other causes of local peritonitis, and kinking of the pylorus from a shortened lesser omentum holding it up against the liver. Usually it will not be difficult to distinguish between obstructive and atonic dilatation of the organ by the presence of visible peristalsis in the former, appearing as a slow wave of contraction passing from left to right. If this symptom can be made out definitely, it is decisive evidence in favour of the diagnosis of obstruction. The presence in the region of the pylorus of a tumour which can be felt by palpation must not by any means be taken as positive evidence of malignant disease. In young infants pyloric obstruction may be due to a congenital thickening and hypertrophy of the walls of the pylorus, which may be felt as a tumour between the navel and epigastrium, and in adults who have suffered from peptic ulceration of the pyloric end of the stomach or first part of the duodenum, a tumour, due to inflammatory thickening of the walls of the pylorus and local peritoneal adhesions, may precisely simulate a malignant growth in the pylorus, not only when palpated through the abdominal wall, but even when exposed to view at a laparotomy.

Another useful means of diagnosis in cases of dilatation of the stomach is by chemical examination of the gastric contents. In cases of gastric carcinoma there is almost always complete absence of free hydrochloric acid in the vomit or in the products of gastric digestion withdrawn by the stomach tube after the administration of a test meal. In cases of peptic ulcer, on the other hand, there is, in the large majority of cases, excessive secretion of hydrochloric acid, or hyperchlorhydria, which can easily be recognised by testing the stomach contents by Gunsberg's reagent, or by the dimethylamidoazo-benzene test. There will also, very often, be a history of prolonged dyspepsia, probably for some years ; while in the case of malignant disease we have usually to deal with a primary dyspepsia of not more than a few months' duration occurring in a patient at or past middle life, who has not previously suffered from indigestion. Undoubtedly, however, a certain number of gastric cancers start in the scar of an old ulcer.

Gastrectasis due to atony of the muscular walls of the stomach occurs as the result of chronic gastritis, long-continued faulty feeding, or as the secondary result of chronic debilitating disease, as anæmia, Bright's disease, or tuberculosis. In this atonic form of dilatation of the stomach the gastric contents usually contain either no free hydrochloric acid, or else a much smaller percentage than the normal ·22 per cent. It is, therefore, obvious that absence of free hydrochloric acid will not decide between atonic dilatation and carcinoma, but the diagnosis must be made after taking many other points into consideration, and especially the presence or absence of gastric peristalsis. Even this latter symptom may lie latent for a time in cases of marked pyloric obstruction, and I have known a case of pyloric carcinoma causing dilatation of the stomach to be under observation in hospital for a week before peristalsis was observed, although it was constantly looked for.

As I have said, it is in the atonic form of gastrectasis that faradism may be of great help in the treatment. It must, however, be applied by means of an intragastric electrode to the interior of the stomach in order to make sure of the faradic current stimulating the muscular coats. If it is attempted to treat the muscular walls of the stomach by means of two electrodes on the surface of the skin, even if one is applied in front over the stomach and the other to the back of the chest, no good effects will be produced, as the current becomes diffused in the abdominal walls and other tissues, causing strong contractions in the abdominal muscles, perhaps, but none in the muscular walls of the stomach itself. One of the electrodes must be passed down the œsophagus into the stomach, while the other is applied to the skin of the abdomen over the front of the stomach.

The intragastric electrode is made of a stiff wire core about 18 inches long, ending in a small grape-shaped knob. From the knob to its upper end the wire core is covered with some smooth insulating material, such as a rubber tube drawn tightly over it. To the other end of the wire core is fixed a binding screw, to which the wire from the battery is attached. If this special form of intragastric electrode is not obtainable, a very serviceable one can be improvised with the assistance of an ordinary rubber stomach tube, such as is used for washing out the stomach, and a 2-ft. length of insulated copper wire.

After lubricating the stomach tube with butter or with glycerine, the patient is placed in a comfortable position on a couch and given a drink of half a pint of water or other liquid, and then the tube is passed into the stomach. Next the insulated copper wire is lubricated and pushed down inside the stomach tube till a length of about 16 inches beyond the teeth has been passed. The lower inch of the insulating covering of the copper wire should have been previously removed, so as to expose the metallic core, which should be bent round to form an oval loop, but not too broad to pass easily into the rubber stomach tube. The other end of the copper wire projecting from the end of the stomach tube beyond the teeth can then be attached by a movable binding screw to one of the wires from the battery, while the other wire from the battery is attached to a moist pad electrode applied to the skin over the front of the stomach. The current employed should be just sufficiently strong to provoke visible contractions of the abdominal muscles, and it should be allowed to run for about ten minutes. This treatment should be repeated every other day for three weeks or a month. A current which is just strong enough to provoke contractions of the abdominal muscles will be scarcely felt in the stomach, especially after it has been running for a few minutes. The current passes between the two electrodes from the bare copper terminal at the bottom of the stomach tube into the liquid contents of the stomach, and so to the stomach walls on its way to the surface electrode, thus directly stimulating the muscular walls of the stomach. It is in order to ensure the copper terminal in the stomach tube being in contact with liquid in the stomach that the patient is made to drink just before the passage of the tube. I prefer this method of applying intragastric faradism because it is possible to wash out the stomach first before passing the copper wire down to the stomach inside the rubber tube; and I think it is usually advisable thus to wash out the stomach previously.

In practice I generally use combined faradism and galvanism (*see* pp. 100 and 127), and it is then easy to tell if the intragastric electrode is properly in position by turning on a few cells of the galvanism and noticing if the galvanometer indicates any current. If the needle does not move, then (supposing all the other attachments are in good working order) it must mean that the stomach electrode does not make contact with the stomach contents, and the copper wire must be pushed in slightly and, if necessary, a little water must be slowly poured through a funnel into the rubber stomach tube.

The effect of the treatment is to cause immediately afterwards a sensation of warmth and well-being in the epigastrium, and in many cases gastric digestion is improved, as evidenced by the return of hydrochloric acid in the gastric juice when previously it has been absent. At the same time, other evidences of dilated stomach—the splashing sounds of succussion and vomiting—will also diminish; while the skin will become clearer, the patient will complain less of eructation, nausea, and insomnia, and will put on weight.

VISCEROPTOSIS

Sometimes the stomach becomes dilated through atony of its muscular walls, and at the same time displaced downwards to the level of the navel or lower. This condition is called gastroptosis, and is often a part only of a more general dropping of the viscera and intestines through atony and lengthening of their suspensory ligaments. The more comprehensive name for this condition is "enteroptosis," or "visceroptosis," in which not only the stomach, but the liver, intestines, spleen, and kidneys all share in the general displacement downwards. It is usually met with in women after thirty or forty, whose abdominal walls are slack and whose muscular tissue generally is deficient; whose lives are almost entirely sedentary; and who have always suffered from chronic constipation.

In the treatment of this condition the aim must be to increase the tone and vigour, not only of the muscular walls of the stomach itself, but also of the intestines and of the abdominal walls, at the same time bracing the system generally by douche baths, massage, and strychnine. Faradism may be of the greatest service, and it is best applied by using one intragastric electrode according to the method already described; while the other wire from the battery is attached to a roller electrode, which is best applied over the course of the colon, starting in the right groin over the ascending colon, passed upwards towards the liver, then across the abdomen and downwards over the descending colon. This treatment should be given for about ten minutes, and is then best followed by another ten minutes' treatment of the intestines. The stomach tube and intragastric electrode are withdrawn, and after two or three minutes for the patient to recover from the unpleasant nausea thus produced, the wire is attached to a rectal electrode and the treatment then given as for constipation in the following section.

Another useful way of treating this condition of gastroptosis with constipation and atony of the abdominal muscles is by means of the three-phase sinusoidal current, one wire being attached to the intragastric electrode, another to a rectal electrode, and a third to a flat, moist pad or roller electrode on the skin of the abdomen. (*See* Chap. XI., p. 299.)

CONSTIPATION

One of the most successful applications of the faradic current is in the treatment of chronic constipation, a form of treatment which has not received from the medical profession the attention that it deserves. Obstinate constipation is so frequently met with in young women, due to deficient muscular power of the intestinal walls, originated often through anæmia, a sedentary mode of life, or neglect to establish regular habits in childhood. Occasionally, though far less frequently, a similar irregular and constipated habit of bowel is met with in men, who have suffered neither from anæmia nor other debilitating illness, and who lead active lives. Many persons suffer from this symptom only on certain diet, especially milk foods, or if they go to reside in a district where the water owes its hardness to an excessive amount of dissolved chalk. Other cases, again, have developed constipation only after some illness, such as gastric ulcer, gall-stones, pericolitis, uterine or ovarian disease, in which the occurrence of a localised peritonitis has been followed by adhesions that have permanently crippled the peristaltic action of the bowel.

Although faradism to the bowel may be of a certain amount of benefit even in this latter group of cases, it is especially in the class of case first mentioned that chronic constipation is most surely relieved, and a regular habit of bowel reinstated, by this form of electrical treatment. Many such cases, if not all, have already tried numerous forms of drug treatment, such as daily pills of aloes, belladonna, and strychnine, or saline water, Epsom salts, senna, and the like, and though relief for the moment is gained by their use, no permanent cure of the constipation is likely to result. I have seen many such cases cured by the use of the faradic current applied by means of a rectal electrode, and I am convinced of its efficacy. The large bowel gradually becomes so dilated and its muscular coats so attenuated in long-standing cases of chronic constipation that little or no power of unaided recuperation remains to the patient. Faradism, when applied to the large intestine, causes a circular contraction at the point of stimulation, and slow peristaltic waves spreading along the bowel from that point. This may be seen experimentally in an animal if the pelvic nerve which innervates the lower portion of the bowel be exposed and stimulated by the faradic current. A similar result, though less marked, follows the direct application of the electrode to the wall of the large intestine.

In the treatment of constipation by faradism, all that is necessary besides the faradic battery and its two conducting wires is a rectal electrode and a roller electrode. The rectal electrode consists of a stout wire about 6 inches long, ending in a small metal knob at one end; at the other it is screwed into a metal cup on the inside of which is a female screw, which fits the screw terminal of the ordinary handle electrode. The 6-inch length of stout wire of the rectal electrode is covered by insulating material from below the metal knob down to the metal cup in which it is fixed, thus leaving exposed only the metallic terminal knob. The patient must lie on the back on a couch, and the electrode is vaselined and inserted into the bowel for a distance of about 3 inches. Before insertion, the electrode has been attached to its handle and one of the wires leading to the faradic battery, and the patient's clothes must be so loosened that the front of the abdomen is easily exposed for treatment with the roller electrode. The battery is now started running with the secondary coil so placed as to give only a weak current, and the roller electrode is then wetted with hot water and applied to the front of the abdomen. If the secondary coil has been well pushed back, the patient will probably feel nothing, but if now the coil be slowly pushed over the primary, the abdominal muscles will presently show signs of contracting to the current, although the patient very likely still feels nothing. The current should not be used in a strength greater than will produce gentle visible contractions of the abdominal muscles.

When the desired strength of current has been attained by thus pushing the secondary coil over the primary, the roller electrode should be slowly pressed over the surface of the abdomen, following more or less the line of the colon, beginning over the cæcum and ascending colon in the right inguinal region, and so up to the right lower ribs, across the abdomen above the navel, and down the left side over the descending colon to the sigmoid. The movements of the roller electrode must be slow, and thus a sort of massage to the large intestine is combined with its direct stimulation by means of the faradic current. It is often recommended in books on electrical treatment, and stated in directions issued with the faradic apparatus by the electrician, that the primary faradic current should be used for stimulation of the intestines; personally, I use only the secondary coil in all cases in which faradism is required. The duration of the treatment should be about twenty minutes, and should be continued every other day until the process has been repeated from fifteen to twenty times. Generally speaking, the treatment should be maintained for at least six weeks. It is best given in the morning about an hour after breakfast, and often the immediate effect of the treatment is that the patient feels a desire to go to stool. Although it is much to be desired that either the doctor or a skilled nurse should give the treatment, it is not impossible for intelligent patients to learn to apply it themselves, just as a patient may learn to wash out his stomach for himself. In the most obstinate cases of constipation the treatment may be given daily, but in the majority it will suffice if it be given three times a week.

Galvanism should never be employed for this treatment. It stimulates the muscular coats of the bowel no better than faradism—indeed, not so well; and there is always a considerable risk of producing electrolysis of the mucous membrane of the rectum when in contact with a bare metal electrode while the constant current is being used. Although the same reasoning might be thought to contra-indicate the use of galvanism with the intragastric electrode in cases of dilated stomach, yet the conditions are then slightly different. The metal knob or terminal of the intragastric electrode should not be in contact with the wall of the stomach, but hidden inside the rubber stomach tube (as I always use it myself); or else if a stout insulated electrode be used without passing it down inside a rubber stomach tube, then the terminal knob dips into the liquid stomach contents, which would serve to prevent any electrolysis of the wall of the stomach, if only weak currents were used. However, the danger of producing such electrolysis is a real one, and its effects might be serious. For that reason, in treating the stomach by this method, when using galvanism to augment the faradic treatment, as in the combined method to be described later, I always take care to reverse the direction of the galvanic current at least once a second, and never to use more than 3 to 4 ma. No nurse or attendant, however skilled, should be allowed to use the galvanic current for intragastric or rectal treatment, or for any treatment in which the electrode has to be applied to a mucous membrane. *A fortiori*, no patient, of course, should be allowed to use galvanism in this way. Faradism, on the other hand, cannot produce electrolysis, and though a clumsy nurse or patient may administer a sharp shock, yet no serious harm is likely to result. Its bark, so to speak, is worse than its bite. The constant current is much more insidious in its action, and a severe burn may easily be produced without very much pain being caused at the time. Its bite may, therefore, be most serious.

PROLAPSE

Prolapse of the **rectum** is liable to occur in young infants and in old people, and in obstinate cases which do not yield to ordinary methods of treatment, faradism by means of the rectal electrode may be called into requisition. It is more likely to be required in old people whose muscles are losing their tone, and whose tissues are shrinking from senile causes, thus depriving the rectum of its previous mechanical support. The treatment may be applied in the same way as for constipation, though the roller electrode is not necessary, and a moist pad placed instead on the front of the abdomen will meet the case.

Prolapse of the **uterus** and displacements due to laxity of ligaments may also be most advantageously treated by the faradic current. The method of application is similar in principle to that employed for the treatment of constipation. A stout bougie electrode, similar in construction to the rectal electrode, is passed into the vagina up to its posterior fornix, and the other electrode employed may be either a roller electrode or [illegible]ist pad placed on the front of the abdomen. If, as is n[illegible] unlikely the case, there is chronic constipation present also, then the roller electrode should be employed on the abdomen in the manner described in the section on the treatment of constipation. The treatment, as in the former class of case, should be given three or four times a week, for a period of about twenty minutes, and should be maintained for from six to eight weeks. I have known chronic prolapse of the womb, which had previously necessitated the persistent use of a pessary, cured by this treatment, and at the same time the chronic constipation from which the patient suffered disappeared.

With some faradic batteries, especially the more expensive ones, an apparatus is supplied by means of which the interruptor can be made to vibrate quite slowly, four beats a second, or even less, being not difficult to obtain. It is effected by fixing an aluminium wire, bent to a sharp angle, upon the rigid interruptor bar and unscrewing the contact screw so that the excursions of the interruptor hammer against the magnet must be larger. If this apparatus is used when giving faradic treatment to the stomach or other viscera, then the muscles are not tetanised by the current as they are when the interruptor is running at the ordinary speed of thirty or forty per second. Instead of a tetanic contraction, the muscles are thrown into rhythmic, clonic contractions, varying regularly in speed with the alternations of the interruptor. By thus allowing the muscle to relax momentarily after each brief contraction, it is sometimes thought that better results may be achieved; but, personally, I prefer the use of the roller electrode with the interruptor working at its ordinary speed.

COMA

This condition, induced by alcoholic or opium poisoning, or respiratory or cardiac failure under an anæsthetic, may advantageously be treated by the faradic current. In an operating theatre an emergency coil is often kept ready for use, should the occasion arise. It consists of a powerful dry cell driving a primary coil with a hammer interruptor. Over the primary coil is permanently fixed a secondary coil, and the starting switch has three or four stops graduating the strength of the current. A pair of wires and disc-electrodes on handles are permanently fixed on to the binding screws, so that the only preparation of the battery necessary is to wet the electrodes and turn on the starting switch. In cases where the respiration or heart has failed under an anæsthetic, the wet electrodes should be placed, one upon the epigastrium or heart, and the other at the root of the neck just behind the sternomastoid muscle. By this means respiration may be stimulated by producing contraction of the diaphragm through faradisation of the phrenic nerve, and contractions of the heart muscle itself may also be provoked.

In the treatment of coma from alcoholic or opium poisoning, especially in the latter, faradism may be of the utmost service. In **opium poisoning** the current may be applied with a small disc-electrode, or with the wire brush to the limbs and trunk, a flat pad as the indifferent electrode being applied to the spine. The current should be sufficiently strong to provoke well-marked muscular contractions. Its value lies in its powerful stimulation of sensory nerves, thereby preventing the patient from relapsing into that depth of coma which is so dangerous to life from the liability to cardiac or respiratory failure. Strong sensory stimulation produced by this means is a far safer means of keeping at bay the dangerous depth of coma in poisoning by opium than the old-fashioned means of walking the patient up and down for hours, until he dies from exhaustion perhaps as much as from the poisonous effects of the drug.

HYSTERICAL CONVULSIONS

Are best arrested by strong faradic stimulation. A large flat pad should be applied to the spine or one thigh, as the indifferent electrode; while for the active electrode a round pad of about one inch in diameter should be used on the chest and limbs. This is a better means of application than by using two disc electrodes in close proximity on the limbs or trunk, as in this latter case the electricity is practically confined to the neighbourhood of the electrodes, and the general stimulation is much less for the same strength of current. Except in very severe cases it will be unnecessary to use the wire brush for this treatment, as it is a much more painful form of application, and is likely to reduce the patient to tears and sobbing, and to induce a state of terror which reacts badly on the condition of the nervous system. Care must, of course, be taken that the diagnosis of hysterical convulsions is correct, and that the convulsions are not epileptic, apoplectic, or toxic in origin. The strength of current that is likely to get the best results is one which will readily produce good, though not violent, muscular contractions.

Catalepsy, whether due to hysteria or to other causes, may usually be arrested by the same form of treatment, though care should be taken to commence with a comparatively weak current, on account of the danger of producing a fatal syncope.

CHAPTER IV

THE GALVANIC, CONTINUOUS, OR DIRECT CURRENT

SULZER, in 1762, was on the track of the continuous current, when he noticed the peculiar sensation produced in the tongue on its being touched by two pieces of lead and silver which were also in contact with each other. Galvani was the first to lay the foundation of our knowledge of the continuous or constant current battery, after studying the phenomena first observed by his wife, in 1789, who produced convulsion of the muscles in a frog's leg by attaching one end of a metallic conductor to the muscles and the other to the lumbar nerves. Volta, soon afterwards, also worked at the same problem, and discovered the voltaic pile, which bears his name, composed of alternate discs of zinc and copper, separated by pieces of acidulated moistened card. It is in memory of these two pioneers in the field of electrical science that this form of current is often referred to as galvanic or voltaic. The name continuous or constant current is also applied to it because the flow of current from a cell which produces it is steady and continuous. When supplied from the electric lighting mains, it is often called the "direct" current, to distinguish it from the alternating current of some electric lighting circuits. This current may be obtained either from primary batteries or modifications of the original voltaic pile, from secondary batteries or accumulators, or from motor generators or dynamos.

The Leclanché battery.—The continuous current is obtained from primary batteries as a result of chemical action. The commonest primary battery used for medical work is the Leclanché, in one of its many modifications. The ordinary wet Leclanché cell consists of an outer four-sided glass vessel, holding from one pint to a quart, which is about one-third filled with saturated solution of sal-ammoniac. In this is placed a rod of zinc, amalgamated with mercury, or, better, a cylindrical plate of zinc, to which is soldered a wire connecting it to the negative electrode. Inside the cylindrical plate of zinc dips a carbon rod, with its lower end packed in a bag of crushed carbon and rough-grained manganese dioxide, or pyrolusite. To the top of the carbon rod is clamped a leaden cap, attached to which is a binding screw for the fixing of the wire of the positive electrode. When this battery is not working, there is, theoretically, no chemical action; but when the wires of the positive and negative electrodes are connected together, either directly or through a resistance, then chemical action is set up in the battery, and an electric current flows from the zinc to the carbon, and through the circuit of the wires back to the zinc. At the same time the zinc is gradually dissolved, with the formation of zinc chloride, while ammonia gas is slowly given off, and the manganese dioxide is reduced to a lower oxide. This cell, when in good order, gives a current of good strength, having a voltage of 1·5, but the carbon soon becomes polarised if the current is taken out rapidly through a low resistance, so that the voltage of the cell rapidly falls. If, however, the cell is left to itself for a time, it gradually recovers, so that it is a cell well adapted for intermittent work, in which heavy currents are not required, as in medical electricity, or for telegraph purposes.

By "polarisation" is meant the covering of the surface of the negative or carbon element with bubbles of hydrogen, as the result of the decomposition of the electrolyte by the passage of the current. The cell may now be considered as a zinc-hydrogen cell, with a voltage of only ·82, instead of a zinc-carbon cell whose voltage is 1·5, and, therefore, the voltage of the battery falls.

In order to oxidise the hydrogen at the negative element, and thus prevent polarisation, a variety of manganese peroxide called pyrolusite is used and packed around the carbon, or incorporated with it. This substance can slowly oxidise the nascent hydrogen to form water, unless too strong a current is taken from the cell. If that occurs, the cell becomes polarised ; but after a period of rest the action of the pyrolusite slowly depolarises the cell again, and its voltage will be found to have risen to much the same as it was before.

Instead of a wet cell, the parts may be arranged as a so-called dry cell, such as that of Hellesen or Obach. This latter consists of a zinc cylinder casing, mounted on an insulating asphalt base. In the centre is placed the carbon rod, which is surrounded by the depolarising mixture, consisting of nearly equal parts of manganese dioxide and plumbago made into a paste with 1 per cent. of gum tragacanth, pressed into the required form. This is wrapped in paper and surrounded with the electrolyte, made of 85 per cent. plaster-of-Paris and 15 per cent. of flour mixed to a thin paste with saturated sal-ammoniac solution. This electrolyte occupies the space between the depolarising mixture and the outer zinc casing. Over the depolariser and electrolyte is placed a paper ring, above which is a layer of ground cork, then another paper ring, surmounted by a bituminous seal, through which a small glass tube is passed to act as a vent for the gases liberated by the action of the cell. The voltage of these dry cells is slightly higher than that of the wet cell, and they last fairly well, though they cannot be renewed as the parts of a wet cell can ; but new dry cells must be bought as the old ones become worn out. On the other hand, a battery of dry cells may sometimes be recharged from a dynamo or main direct current, just as though they were accumulators (*see* p. 115).

Electrical units.—The *volt* is the arbitrary **unit** of electric pressure or **electromotive force,** and is a little less than that of one Daniell cell. This cell consists of an outer glass or porcelain vessel containing a zinc cylinder standing in a solution of dilute sulphuric acid. Inside the zinc cylinder stands a porous pot containing a rod of copper immersed in a saturated solution of copper sulphate. When the cell is in action the zinc dissolves in the sulphuric acid, forming zinc sulphate, and the liberated SO_4 ion sets free copper from the copper sulphate solution, and copper is deposited upon the central copper rod, which therefore grows thicker. This cell is very constant, and its voltage is 1·1.

The **unit of resistance** is the *ohm*, and is fixed as the resistance of a column of mercury 106 mm. high and 1 sq. mm. in cross section, weighing at 0°C. 14·4521 grammes. This is equal to the resistance of a wire of pure copper 1 mm. in thickness and a little over 50 yards in length.

The **unit of electric current** is the *ampère,* and is the measure of the current that will flow through a resistance of 1 ohm at the pressure of 1 volt. In medical electricity the ampère is too large a unit to be convenient, and the thousandth part of an ampère, or milliampère (ma.) is employed instead.

The unit of quantity is the *coulomb*—a term scarcely ever required in medical electricity. It is the quantity of electricity represented by a current of 1 ampère flowing for one second. A coulomb may also be defined as the quantity of electricity which, when passed through a solution of silver nitrate in a silver voltameter, causes a deposition on the platinum kathode of ·001118 gramme of silver. In electrical engineering a larger unit is more commonly used: the *ampère-hour;* that is to say, a current of 1 ampère flowing for one hour, or 3,600 coulombs.

The unit of capacity, or storage-power of a condenser, such as a Leyden jar, for electricity, is the *microfarad,* or the millionth part of a *farad.* A condenser has the capacity of one farad, which would require one coulomb of electricity to charge it to the pressure of one volt.

The **unit of electric energy** is the *watt*, and is the measure of the rate at which work is being done. The number of watts consumed is obtained by multiplying the number of volts of electric pressure by the number of ampères of current flowing. Thus a current of ½-ampère at a pressure of 100 volts will do work at the rate of 50 watts. The amount of work done is usually reckoned in *watt-hours*, and 1,000 watt-hours is the **Board of Trade unit** for electric supply, and costs usually about sixpence for electric lighting. It can, however, be manufactured in this country for about one halfpenny in large power stations.

Seven hundred and forty-six watts are equivalent to one electrical horse-power: a force which will raise a weight of 550 lb. to a height of 1 foot in one second.

One thousand watts, or a *kilowatt*, is the unit of electric energy commonly used by electrical engineers in measuring the power of large machines.

Since the number of watts, or rate at which work is being done, is the product of the voltage multiplied by the ampèrage, it will be clear that a current of 1 ampère at a pressure of 200 volts will do exactly the same amount of work as a current of 2 ampères at a pressure of 100 volts. In reckoning the comparative efficiency of machines or electric lamps, it is usual to quote the number of watts required to work them. Thus the ordinary 16-candle-power incandescent lamp requires about 60 watts to make it glow brightly, and therefore on a circuit of 100 volts a 16-candle-power lamp will consume ·6 of an ampère, while on a circuit of 240 volts a lamp giving the same candle-power will require only ·25 of an ampère. The lamps must be specially made for the different pressures, and if a lamp designed for a 100-volt circuit were accidentally fitted on to a 240-volt circuit, as soon as the current was turned on it would glow with intense brightness for a fraction of a second and then be destroyed. Hence the voltage of the lamps is always indicated upon the glass bulbs. Some modern incandescent lamps, with metallic, instead of carbon, filaments, have a higher efficiency—such as the Tantalum or Osram lamps, producing the same candle-power at an expenditure of from two-thirds to even one-third of the number of watts required to drive the ordinary incandescent lamp. Up to the present, however, it has not been possible to obtain metallic filament lamps designed to withstand a higher pressure than 130 volts.

Ohm's Law.—For galvanic currents of comparatively low voltage, Ohm discovered that in any circuit the resistance is inversely proportional to the strength of the current. From this he deduced the law that bears his name: "The strength of the current in ampères is equal to the electromotive force in volts divided by the resistance in ohms." This may be expressed by the formula, $C = \frac{E}{R}$, where C = the strength of the current in ampères, E the electromotive force in volts, or **EMF**, and R the resistance in ohms. This law does not apply except in a modified form to currents of high voltage, such as are produced by static machines, or currents of high frequency, in which the current practically passes only along the surface of the conductor. This is known as the "skin effect." If the conductor is wound in a spiral, the self-induction set up in the neighbouring turns of wire acts as an enormous resistance.

When dealing with an electric battery as the source of supply of the current, we have to reckon in the sum of the resistances of the individual cells, or the internal resistance of the battery, in addition to the sum of the total resistances in the external circuit. Thus the equation may be written $C = \frac{E}{R + r}$, r indicating the total internal resistance of the battery. Small Leclanché cells have a higher internal resistance than large ones, the resistance of the latter being about ·7 ohm when in good working order.

Batteries and accumulators. -- The arrangement of the cells in a battery will vary according to the work that it is required to perform. If a high voltage is required, and no great ampèrage of current, as in the treatment of patients with the galvanic current, then a large number of small cells must be used, instead of one or more large ones. These small cells must be coupled up in series; that is to say, the zinc of one cell must be joined by a wire to the carbon pole of the next, and so on throughout the whole number of cells employed, the unattached carbon pole at one end of the battery and the unattached zinc at the other being fixed to the wires, which are fastened to the treatment electrodes. By this means of coupling up the cells, the total voltage of the battery is the sum of the voltages of the individual cells. Thus, a battery of forty cells will have an available voltage of 60 volts when the cells and working parts are new and bright.

This high voltage is necessary in medical treatment because of the high resistance in ohms offered by the skin, even when thoroughly moistened. The resistance of the moistened skin to the passage of the current from two ordinary pad electrodes may be taken, on the average, as about 3,000 ohms. This resistance R is very great in comparison with r, the sum of the internal resistances of the cells, even if we estimate the internal resistance of each cell as high as 4 ohms. Thus, $C = \frac{E}{R + r} = \frac{60}{3{,}000 + 160} =$ ·019 ampère, or 19 ma. Now, 19 ma. is a fairly strong current for medical therapeutics, and will rarely be required, except in the treatment of sciatica. Hence, a battery of 40 cells will be found amply sufficient for all the purposes of galvanic treatment. It will be noticed how small a proportion the internal resistance of the battery bears to the external resistance—namely, that of the patient's skin and tissues; and the internal resistance r of the battery may safely be neglected in working out the sum to find out either the milliampèrage, the voltage, or the resistance of the circuit, when two of the three factors are known.

Far otherwise is it when a large ampèrage of current is required at a low voltage to heat a cautery, or to drive a motor. To heat a cautery a high voltage is not necessary, but a large volume of current is required—often 20 ampères. To obtain such a current from a primary battery, large cells must be used, and they must be coupled up in two groups, the cells arranged in parallel. In each group all the zincs are joined together, and also all the carbons, so as to make in effect one large cell of large surface. The total voltage of each group is no more than that of one cell, but the internal resistance is much diminished, being the average resistance of one cell divided by the number of cells. To obtain the *maximum effect* from a multiple-cell battery, the cells must be so arranged that the internal resistance r of the battery equals the resistance R of the external circuit. In cautery work R is very small, perhaps not more than .06 ohm, and therefore if C is to be large, it is of the utmost importance to keep r as small as possible. For this reason chromic acid cells or accumulators should be used. If even large Leclanché cells, whose internal resistance is ·7 ohm, were used to heat a cautery with a resistance of ·06 ohm, using the equation $C = \frac{E}{R + r}$, in order to get 20 ampères of current we should require at least thirty-six cells, arranged in two groups of eighteen cells, each group arranged in parallel. This is an impracticable number to use for this purpose, and even this number of Leclanché cells would soon fail to give such a heavy current, on account of the cells soon becoming polarised. Leclanché cells are, therefore, unsuitable for this class of work, requiring heavy currents; and it will be found far more convenient to use a small battery of accumulators, whose internal resistance is extremely low, and therefore eminently adapted for this kind of work.

Accumulators can, moreover, give out a heavy current at a steady rate for a comparatively long period. Accumulators, when fully charged, may be reckoned to supply current at a pressure of 2 volts per cell, until about 75 per cent. of their charge is exhausted. A two-cell accumulator battery, coupled up in series, with a capacity of 45 ampère-hours, will, owing to the almost negligible internal resistance of the cells, be able to supply enough current for the largest surgical cautery. Its weight will be about 24 lb., and its cost about £3 10s. In medical and surgical practice, it will be found most convenient, therefore, to use a battery of accumulators for cautery work, or to light incandescent lamps for use with the cystoscope, the sigmoidoscope, for illuminating the interior of the mouth and throat, or other purposes. In most districts it is comparatively easy to get these small accumulators recharged at a low cost owing to the advent of the motor-car having made the small accumulator for ignition purposes a comparatively familiar object.

Secondary batteries or accumulators.—A secondary or storage cell is one which may be charged from a source of electricity such as a battery of primary cells or a dynamo. They are usually built up of lead plates in sets of three, each secondary cell having one positive and two negative plates. The positive plates are covered with a paste of peroxide of lead, and the negative plates with spongy lead. The plates dip into a dilute solution of sulphuric acid, 1 part of acid to 5 parts of water; and the receptacle to hold the plates may be of celluloid, ebonite, or lead. Binding screws, with wires, are attached to the positive and negative plates. The spongy lead at the negative plate, and the lead peroxide at the positive in the acid electrolyte, form an electric cell in which the spongy lead is positive and the peroxide of lead negative. When the terminals of this cell are joined by a wire through an external circuit, then a current passes from the spongy lead through the liquid to the lead peroxide, and out through the positive binding screw attached to the peroxide plate. This cell has an EMF of a little over 2 volts. In this process the spongy lead dissolves in the acid to form lead sulphate, which is deposited on the plate, the hydrogen combining with the oxygen of the peroxide on the other plate, on which lead sulphate is also formed. The acid is thus gradually used up, and its specific gravity falls, and after a time the voltage of the cell drops below 2; this occurs when about three-quarters of the total electric charge has been withdrawn, and the cell should then be recharged before being used again. If a dynamo or battery of large primary cells is connected to this lead cell, positive to positive, and negative to negative, and if the EMF or voltage of the dynamo or battery is greater than that of the lead cell, a current will flow into the lead cell in the reverse direction, and the effect of this is to reverse the previous chemical process, so that lead peroxide is re-formed on the positive plate, and spongy lead on the negative. This is what is meant by charging the cell or accumulator. There is no actual storage of electricity as such, but the work done by the charging electric current causes a chemical dissociation in the storage cell, so that the chemical affinities of the spongy lead and peroxide of lead with the dilute sulphuric acid are again available for combination, with the accompanying evolution of an electrical current. It will be noticed that the anode or positive plate, and the kathode or negative plate, are so called because the binding screws and wires attached to them in the external circuit are respectively positive and negative, though in the cell itself the so-called negative plate, or spongy lead, is positive to the peroxide plate.

A storage cell is, therefore, directly comparable to a Leclanché cell, in which the zinc in the cell is positive to the carbon, though the binding screw and wire attached to the zinc terminal are negative.

Further, a Leclanché dry cell, if recently run down, may be recharged just like an accumulator cell, using a dynamo current or strong primary battery for the purpose. If the cells have dried up, and the current cannot be made to pass into them, standing them in water deep enough to cover the open vent holes, for a quarter of an hour or more, will correct the defect. This knowledge may be of use to those who use a dry battery for galvanisation, or for lighting a small head lamp, such as the "Ever Ready," for throat or ear examinations. This instrument is a very handy and compact form of head lamp, fitted with a 7-volt lamp and driven by a small battery of five dry cells in series, in a leather case, with plug attachments and wiring. The five cells, when new, have an **EMF** of 7·5 volts, and light up the lamp brilliantly; but after repeated use, or in a couple of months if the instrument is not much used, the voltage of the cells falls below 7, and the lamp now gives insufficient light. A new set of cells costs half-a-crown, but the voltage of the old cells may be quickly renewed, and the lamp regain its brilliance, if the cells are recharged as though they were an accumulator. I recharge mine, when necessary, from my wall apparatus for using the direct main current, graduating the voltage by the sliding rheostat until a current of 150 ma. is shown on the galvanometer. Before the wires from the main apparatus are joined on to the cells, care should be taken to push the sliding spring of the rheostat sufficiently far to provide an available voltage approximating that of the cells, or else the cells will at once discharge in a short circuit through the apparatus at a rate of perhaps several ampères. The sliding spring contact should then be moved backwards or forwards so as to bring the needle of the galvanometer to zero, when the voltage of the cells and of the charging apparatus are in equilibrium. Then increase the voltage by pushing on the spring until a current of 50 150 ma. is shown on the galvanometer; this is allowed to run for twenty minutes or longer, according to the number of cells and their condition, when they will be again available for use. When the charging is completed, as will be indicated by bubbling from the vent holes of the cells, the battery of cells must be disconnected from the wires joining it to the charging apparatus before the current is turned off, or else they will be short-circuited. If a battery for galvanisation is being recharged in this way, its galvanometer should first be taken out of the circuit.

Accumulators have practically a negligible internal resistance, and they are therefore excellently adapted for cautery work, where a heavy current has to be driven through a very low resistance in the external circuit. Their capacity is spoken of in terms of "ampère-hours," being the rate of discharge in ampères multiplied by the number of hours it can be maintained.

They must be kept vertical, or the acid will spill, and they must not be jolted, or the plates are liable to break, or the peroxide of lead is liable to become detached from the positive plate. Lastly, they should never be allowed to remain long in an undischarged state, as they then rapidly deteriorate. Their EMF and capacity improve after they have been charged and discharged several times, owing to the increased formation of spongy lead on the negative plates; and they are kept in the best condition if they are in constant steady use, and are recharged as soon as their voltage falls below 1·8 volts per cell.

For therapeutic use, the galvanic current will be best obtained from a battery of dry cells, which requires no attention on the part of the user, and which will give a fair current with moderate daily use for about a year. When exhausted, these cells will have to be replaced by new ones at a cost of 1s. 6d. each, unless their voltage can be renewed as described above, so that a battery of forty cells will cost about £3 yearly to renew, if in fairly constant use. The faradic battery, on the other hand, is much cheaper to run, as the renewal of the two large cells required to drive the coil will cost only 5s. every six or twelve months, according to the amount of work demanded of it.

Tests for polarity.—All galvanic batteries should be marked by the maker so as to indicate the sign of the electrodes; that is to say, which binding screw is negative and which positive. Since the zinc is the electropositive element, the zinc dissolving in the solution, while the current flows in the cell from the zinc to the carbon, it is obvious that the current leaves the battery and enters the wires of the external circuit from the carbon or negative element, which is therefore attached to the positive electrode; while the zinc, which is the positive element, is attached to the negative electrode. The zinc terminal of the battery will, therefore, be marked by a negative sign, −, while the carbon terminal will be marked by the positive sign, +.

It is always wise, however, to test the battery oneself, and not to trust entirely to the instrument maker, and to test the poles is quite a simple matter. One way is to connect two wires to the binding screws of the battery, and after turning on twenty or more cells, dip the two free ends of the wires into a tumbler of water, holding the points about ½ inch apart. The point which bubbles most is the negative electrode, and is that attached to the zinc element of the battery. This bubbling is due to the evolution of hydrogen, owing to the decomposition of the water. Unless platinum or gold electrodes are used, there will be no bubbling of oxygen at the positive electrode, owing to the oxidation of the metallic points.

Another convenient way of testing the poles of the battery is to use a piece of pink litmus paper. When the litmus is moistened, if the two free ends of the wires that are attached to the battery are placed about ¼ inch apart upon the wet litmus, after turning on a few cells, the negative electrode will make a bright blue mark on the pink litmus, owing to the production of alkali at the negative electrode. Similarly, acids are produced at the positive electrode, which turn blue litmus pink; but the change in colour is not nearly so pronounced as the blue discoloration of the pink litmus by the negative electrode.

When once the battery has been tested and the poles are correctly marked, it is impossible for the polarity to become changed until the battery is taken to pieces and the cells renewed. If, however, the electric light main is used, reducing the voltage through a shunt resistance, then the polarity of the binding screws for the attachment of the electrodes may easily become changed, owing to the wall-plug attachment having been turned round, unless it is of the old-fashioned concentric pattern.

Effects of galvanism on the skin.—The action of the two poles on the skin and tissues is somewhat different. If the wires be attached to two equal-sized electrodes of about 1 inch diameter, and a current of 2 to 3 ma. passed after applying the moistened electrodes to the skin at a few inches apart from each other, it will be noticed that the negative electrode, or kathode, is much the more painful of the two. If the electrodes be left closely applied to the skin, and a current of that magnitude passed continuously for half an hour or more, probably electrolysis of the skin will take place; on removing the electrode one or more sore places will be found, ulcers which take a considerable time in healing. This is more liable to occur if the surface of the electrode presses unevenly on the skin, a result which is very common from bending of the electrode, or from a depression in the plate electrode occurring at the point of attachment of the binding screw.

Bare metal should never be allowed to touch the skin, and all electrodes should have metal surfaces, which can be covered with padded webbing, or chamois leather, or other absorbent material. This padded cover to the electrode serves two purposes: first, by retaining moisture, it makes good electrical contact between the metal of the electrode and the skin; and, secondly, it prevents burning of the skin to a great extent, the electrolytic action taking place in the moisture of the pad instead. The webbing or chamois leather surface of the electrode should be made easily removable, and should be changed frequently. One great danger in using old, worn pad electrodes is that a corner of the metal disc or plate may come in contact with the skin, and if a continuous current of any strength is being employed, and the pad is not being moved about, a severe burn will quickly occur, for practically all the current passing through the pad will then rush through the exposed metallic contact with the skin, owing to the far smaller resistance at this spot. If the electrode be allowed to remain in contact with the skin for some minutes, the skin will be found afterwards to be bright red from dilatation of the superficial vessels; and if the current density be too great, then after some minutes small yellow blisters will appear, which break down into ulcers and are somewhat painful and troublesome to heal. The patient's sensations are not always sufficient guide to what is occurring, and though he will probably feel considerable discomfort, he may not draw sufficient attention to what is happening until it is too late. When passing a continuous current of 3 ma. or more through padded electrodes for more than five minutes, it should always be made a rule to inspect the skin under the electrodes, especially the negative electrode, every few minutes, and if any suspicion of blistering is seen the electrode must be moved or the treatment stopped. To ensure safety, I always use a pad of wetted cotton wool between the electrode and the skin.

Padded electrodes, even though thoroughly wetted before being fastened in position, invariably dry more or less rapidly from the warmth of the skin, and therefore it will be necessary to wet the pads again every six or seven minutes. Chamois leather will be found to retain the moisture longer than flannel, which soon dries, and, when new, flannel covering to plate electrodes will hardly retain any moisture at all on account of the greasy dressing present in the material. This should be washed out with soap and water.

As a rule, hot water is all that is necessary for wetting the electrodes; but in case the electromotive force of the battery should be scarcely sufficient, the resistance of the skin may be further diminished, and the current correspondingly increased by wetting the pads with strong solution of sodium bicarbonate. This is better than using salt solution. After a pad electrode has been in position for some time, and the continuous current running, the drying of the pad will be accompanied by a fall in the amount of current passing, and yet at this time the patient often complains of a burning sensation under the pad. This is due to commencing electrolysis of the skin, owing to the disappearance of the moisture from the pad; the remedy will be to again wet the pad thoroughly. Although, by thus diminishing the resistance more current is allowed to pass, yet the process of electrolysis is transferred from the surface of the skin to the interior of the pad, and the burning sensation ceases.

It is of some importance to remember that the amount of pain produced, or the danger of burning of the skin, by the passage of a continuous current, depends very largely upon the size of the electrodes which are in contact with the skin; that is to say, upon the *density of current* per square inch of electrode. As a rough measurement, not more than 1 to $1\frac{1}{2}$ ma. of current per square inch of surface of either electrode should be used for treatment, if the current is allowed to run steadily without moving the electrodes. For example, if two flat electrodes, each 6 inches by 4 inches, are used in the treatment of a case of sciatica, by application to the buttock and leg, then not much more than 24 ma. of current should be employed. On the upper extremity not more than half this amount should be exceeded. When, however, there is a large area of skin contact, as in Apostoli's method of electrolysis of uterine fibroids, in which a large wet clay electrode is applied to the front of the abdomen for the positive pole, as much as 150 ma., or even more, have been used.

Again, if the patient's body is immersed to the neck in an electric bath, much larger currents may be passed through the body without causing any pain or injury to the skin, than can be passed through an electrode 6 inches by 4 inches. In an electric bath the whole area of the skin in contact with the water acts as an electrode; and though the parts nearest the metallic electrode which conducts the electricity from the battery to the water will receive a greater density of current in proportion than the parts of skin more distant, yet a large quantity of current may be passed through the body without the density of current per square inch of skin surface approaching that of 1 ma. On the other hand, when the electrode surface in contact with the skin is made very small, then a small strength of current, as shown on the galvanometer, may cause severe pain. In an extreme case, as in using a needle electrode for electrolysis, if the negative electrode is attached to the needle, and the point applied to the skin, the passage of even ½ ma. of current causes a sharp pain, like the sting of a wasp.

It must be remembered that the negative electrode, or kathode, is the more painful of the two, and its action is more stimulating than the positive electrode, or anode, which has certain sedative properties. The negative electrode is the stimulating electrode, and causes brisker muscular contractions than the anode. The negative is also the active electrode which is used in the electrolysis of naevi, etc. In electroplating it is the negative electrode to which are attached the metallic objects that have to receive the coating with silver, gold, or nickel. These pages are not the place to enter into a physiological discussion of the action of the constant current on nerve and muscle tissue, and we shall content ourselves with describing its effects as illustrated in medical treatment.

Effects of galvanism on muscle. If the continuous current be applied to the skin by means of moistened electrodes, and a current of about 4 or 5 ma. turned on, at the moment of application of the current, and for as long as it passes, will be felt a sharp, stinging sensation or gentle pricking, according to the density of the current per square inch of electrode contact with the skin. If one of the electrodes is a small disc of about 1 inch in diameter, and if it be applied to the skin over the motor point of a muscle —that is to say, over the point where the nerve supplying a muscle enters it—at the moment of contact of the electrode with the skin the muscle will contract with a sharp twitch, and then will remain quiescent.

Although the muscle twitches at the moment of application of the wet electrode over its motor point, yet it is not thrown into a series of contractions, or tetanus, as happens when the interrupted or faradic current is used. When the electrode is removed, there is, as a rule, no visible contraction, because with a normal muscle there is no visible contraction produced at the break of the current, unless the current is very powerful - too powerful to be borne. The contraction produced at the moment of application of the current is called the contraction "at make," or KCC. That produced at the break of the current is known as the opening contraction, or KOC; KCC = kathodal closure contraction, while ACC = anodal closure contraction; KOC = kathodal opening contraction, and AOC = anodal opening contraction.

With normal muscle, the contraction produced by the closure of the current at the kathode, KCC, is decidedly stronger than that produced by the closure of the current at the anode, ACC. This is usually written KCC > ACC. As has just been said, with normal muscles the opening contractions KOC and AOC are not seen, except with powerful currents. Personally, I never use, nor do I advise the use of, a special "testing electrode" with an interruptor on the handle. This interruptor is very liable to fail in its insulation, so that the patient is likely to get a full shock of current at a moment when the operator thinks it is not possible; and, again, with an interruptor on the handle the operator himself is very liable to get a shock in his fingers when least expecting it. Moreover, when testing electrical reactions with it, it is less suitable than an ordinary electrode, because with faint muscular contractions in a degenerated muscle it is very difficult to tell between a small contraction and the slight jar given to the muscle by the slight movement of the electrode in the action of moving the interruptor. It is much better in muscle testing to hold the electrode firmly on the point to be tested, and to interrupt or reverse the current at the battery.

The interruptions of the galvanic current are best done by moving the first handle of the double collector on and off the dummy knob which is unattached to a cell; this is usually the second knob. If there is only a single collector handle, with a combined battery the galvanism is best interrupted by moving the De Watteville switch from G to F, and *vice versâ*, or with a plain galvanic battery by breaking the connection at one of the binding screws by moving the electrode wire. Although the weak currents of medical batteries do not produce tetanic contraction of normal muscles, but only a twitch on closure of the current, this rule does not apply to powerful currents at higher voltages, as at 100 and 240 volts, such as are supplied by electric lighting companies, or the 500 to 550-volt currents supplied to the trolley wire or third rail of electric tramways or railways. If by accident a good contact is made between the skin and a wire carrying one of these heavy currents, then tetanus of the muscles is set up just as by strong faradism or an alternating current; and if the hand happened to grip the wire, the unfortunate person may be unable to let go, and may suffer severe burns or death.

Electrotonus.—When a galvanic current is passed along a nerve, the excitability of the nerve at the points where the current enters and leaves it is augmented at the kathode and diminished at the anode. This can be shown in an isolated muscle-nerve preparation of a frog's sciatic nerve and gastrocnemius muscle. If the nerve be laid across two non-polarisable electrodes between which a weak galvanic current is flowing, it will be found that stimulation of the nerve, by single faradic shocks or by other mechanical means of constant strength, will produce stronger muscular contractions when applied in the neighbourhood of the kathode, and weaker contractions when applied nearer to the anode, than when no galvanic current is passing. Thus, the passage of a steady galvanic current through a nerve along its length raises the excitability of the nerve in the neighbourhood of the kathode, and depresses it in the proximity of the anode. The heightened excitability in the neighbourhood of the kathode is spoken of as katelectrotonus, and the lowered excitability near the anode as anelectrotonus.

The conditions of an isolated muscle-nerve preparation, however, cannot be exactly imitated in medical applications, because the nerve lies deeply imbedded, surrounded by muscles and other conducting tissues, and the reactions are on this account somewhat different. Owing to the fact that the electrode cannot be applied directly to the nerve, but only to the skin at some little distance from it, the lines of force from the electrode pass into the nerve by diffusion of current both in an upward and in a downward direction, so that there are two virtual poles produced in the nerve by the action of each electrode—a polar and a peripolar of opposite sign. That is to say, in the nerve under the kathode there is a polar kathodal zone, and a peripolar anodal zone, and similarly an anodal polar and a kathodal peripolar zone will be developed in the neighbourhood of the anode. Owing to this presence of four poles in the nerve that is being tested, instead of the two poles in the case of the isolated muscle-nerve preparation of the frog, we shall get four different reactions to the poles instead of only two, as in the frog's nerve. In this latter case, Pflüger long ago showed that contractions only occurred owing to the sudden appearance of a positive state of electrotonus. Now this positive electrotonus is set up at the kathode at the make of the current, producing katelectrotonus, and therefore the contraction KCC. When the current is made at the anode, there is a lowering of electrotonus (anelectrotonus), and therefore no stimulation, ACC, at the anode at make of the current. When the current is broken, the positive electrotonus at the kathode instantaneously falls to a negative state, and therefore there is no contraction, KOC, from the break of the current at the kathode. At the anode, however, at break of the current there is an immediate rise of electrotonus from the negative state of anelectrotonus to the reversed or positive condition, which, as Pflüger has taught us, stimulates the nerve to produce a contraction, AOC. Thus, in the isolated muscle-nerve preparation there are only two contractions, the KCC produced by the stimulation of the nerve at the kathode at the make of the current, and the AOC or anodal opening contraction produced at the anode at the break of the current.

If, instead of merely slowly making and breaking the current sent through the nerve of the muscle-nerve preparation, we suddenly reverse the direction of the current, so that the point which was previously anode is now made kathode, we shall find that we obtain distinctly stronger contractions than by simply making and breaking the current slowly. This is due to the fact that on reversing the direction of the current, the kathodal closure positive stimulation is superadded to the anodal opening positive rise of electrotonus at the same point of the nerve—namely, at the point which was just previously anode and has now suddenly been made kathode. Another way of putting it is to say that KCC is superadded to AOC. Now, we have seen that in the human conditions, owing to the electrode being necessarily placed at some distance from the nerve, and the current in its passage not being limited to the nerve, but being diffused into the surrounding tissues, we have four possible contractions—namely, KCC, ACC, AOC, and KOC, the two new ones, ACC and KOC not having been seen in the muscle-nerve preparation. The KCC is always normally the strongest, the ACC coming next, followed closely by the AOC, and the KOC last. KOC, indeed, is very difficult to obtain, and only with very strong currents, too painful to be borne. As previously mentioned, sudden reversal of the direction of the current produces stronger contractions than simply making and breaking the current.

It is in order to avoid having four poles on the nerve that is being tested that in muscle testing it is necessary to have one electrode, the so-called indifferent electrode, placed at a distance, as on the back or chest. The results thus obtained are more constant and less liable to error than if the two electrodes be placed upon the same limb, especially if at all near each other. It will be noticed, moreover, that stronger contractions are obtained after letting the current run for a few seconds, and then quickly reversing, than if the reversals are made one after the other without pause. This stronger contraction is due to the condition of katelectrotonus, and therefore increased excitability, set up in the nerve by the passage of the constant current, which effect will be wanting if the reversals be made in each direction too frequently.

This katelectrotonic effect upon the nerves produced by the passage of a constant current is well seen when **combined faradism and galvanism** are applied to the muscles at the same time. This can be done when two separate batteries are used—one for galvanism and one for faradism—by joining the negative pole of the galvanic battery to the positive of the secondary coil, and then attaching the electrodes and their wires to the negative pole of the coil and the positive pole of the galvanic battery. By this arrangement the faradic current has to pass through all the cells of the galvanic battery that are being used, before reaching the patient, and the galvanic current has to pass through the coil of the faradic apparatus. These arrangements interpose an extra resistance to the passage of each current, and therefore the strength of the galvanic or faradic current will, in each case, be slightly weaker than if they were applied directly from the battery in the ordinary way, using the same number of cells for galvanism, and the same position of the coil on the scale for the faradism. The effect, however, after turning on a few cells of the galvanic battery, will be shown by increased strength of the muscular contractions obtained by a given strength of faradic current, increased roughly in proportion to the strength of the galvanic current thus turned on. This effect can be easily demonstrated by using single faradic shocks, moving the interruptor slowly by hand, and noting the point on the scale of the secondary coil where muscular contractions first begin to appear. Then turn on, say, ten cells of the galvanic battery, when the muscular contractions now resulting from the same single faradic shocks will be seen to be considerably stronger, whether the kathode or anode is applied to the muscle, though stronger with the kathode. In the so-called combined batteries that are made, with both faradic apparatus and separate cells for faradism and galvanism, both currents are led to the same pair of binding screws, and by means of a switch, known as the De Watteville switch, either faradism or galvanism may be used separately; or, by turning the switch half-way only, the combined current may be used as just described, the galvanic cells and the faradic coil being thus coupled up in series.

The instrument makers are very liable to overlook the point that the galvanic cells and the faradic coil must be coupled up in series, and sometimes they are just as likely to couple them up in parallel; that is to say, negative pole of galvanism to negative pole of faradic battery, and positive pole to positive pole. If this has been done, when using the combined current the faradic contractions will become weaker instead of stronger as the galvanic current is turned on. This faulty method of coupling up the faradism to the galvanism will not matter so long as the two currents are used separately, but will only affect the results of combined current treatment. The easiest way to test the battery for this point, after it has come home from the makers, is to apply slowly interrupted faradic shocks to a muscle, noting the minimum point on the scale at which slight but definite contractions are first seen; then, with the De Watteville switch placed half-way between F and G, turn on about ten cells of the galvanism, and note if the muscular contractions resulting from the faradic shocks are made stronger or weaker. If they are made stronger after turning on the galvanic current, then the apparatus has been coupled up in the right way; but if the contractions are weaker instead of stronger, then the faradic coil and the galvanic cells have been coupled up in parallel, instead of in series, and this has to be altered.

The easiest way to alter it is to undo the wire connections of the special cells which drive the faradic coil, and then reverse, so that the wire which was previously attached to the zinc of the battery should then be fixed to the carbon, or copper, according to the make of battery that is being used. By doing this, the direction of the battery current in the primary coil is reversed from what it was before, and consequently the extra induced primary current, and the induced currents in the secondary coil, will be also reversed in direction. Now, it is only the induced current at break which is of any practical use in a faradic apparatus, so that the current of a faradic battery is practically unidirectional, though of course interrupted; and, therefore, one may speak of a positive and a negative pole for the faradic current, as we do for the current from a battery of galvanic cells.

REACTION OF DEGENERATION

The continuous current, when applied to normal muscle, stimulates the nerve-endings in the muscle, so that the resulting contractions are quick twitches, similar to those produced by single faradic shocks. When, however, the nerve supplying the muscle has been injured, then the nerve degenerates and the muscle substance also becomes altered and degenerates also. When this is the case, the application of the faradic current over the muscle or motor point no longer produces any contraction, even with as strong a current as can be borne. Application of the continuous current now no longer produces the quick twitch as in the normal muscle; but a new type of contraction is seen: a sluggish contraction, slowly developed and slow to relax, though often a larger contraction than the same strength of current would produce in the normal muscle. This phenomenon is called the "reaction of degeneration." This form of contraction is produced by the direct stimulation of the altered muscle substance by the continuous current, not by any stimulation of the nerve-endings in the muscle. The excessive contraction of the degenerating muscle to even weak galvanic currents of 1 or 2 ma. is called "hyperexcitability to galvanism."

In addition to these phenomena, there appears an alteration in the relative strength of the contractions at the kathode and the anode. Whereas in normal muscle the kathodal closure contraction is stronger than the anodal closure contraction, or $KCC > ACC$, when the nerve is degenerated as the result of an acute lesion there is a change in the polar reactions, and very often it will be found that KCC [illegible] ACC, or even that $ACC > KCC$.

Sometimes, in the more acute forms of nerve injury, especially in lesions of the musculo-spiral nerve, as in crutch or sleep palsy, besides the above described forms of change of reaction, it will be found that tetanic contractions in the paralysed muscles may be set up by closure of the current at either the kathode or anode.

These changes, known as the reaction of degeneration, do not occur when the nerve and muscle both waste very slowly, as in progressive muscular atrophy. The reaction of degeneration, or RD, as it is often spoken of, occurs only after sudden or acute damage to the nerve-cells in the anterior horn of the spinal cord, or to the nerve fibres proceeding from these cells to supply the muscle. Thus, RD will be found in the paralysed muscles in cases of infantile paralysis, in which the anterior horn cells in the spinal cord are acutely damaged; in neuritis of the nerve trunks, as the result of inflammation or pressure, as seen in facial paralysis, crutch and sleep palsies, etc.; or in acute inflammation of the peripheral endings of the motor nerves, as in multiple neuritis.

The alterations in electrical reactions of nerve and muscle are not found immediately after the damage has taken place to the nerve or nerve-cell in the cord; and, therefore, it is clear that the electrical change is not due merely to the cutting off of the nervous impulses from above. Four to seven days elapse before the electrical changes become noticeable, and since about this time structural changes can be demonstrated microscopically in the nerve and muscle tissue, the changes must be due to chemical alterations in those structures.

Reaction of degeneration in the *nerve* is shown by the less of power of conduction either of faradic or galvanic impulses along it; normally, stimulation with either current over a motor nerve produces brisk contraction of the muscle supplied by it, tetanic contraction in the case of the interrupted current, and a single twitch in the case of the galvanic. Reaction of degeneration in the nerve differs from RD in muscle, for in the nerve there are no polar changes and no preservation of contraction to one current and not to the other. All that happens is the rapid disappearance of conductivity of the nerve to either current. Before this takes place, there may be noticeable for a day or two, soon after the injury, a slight degree of hyperexcitability in the nerve to either current, so that stimulation of the nerve on the damaged side elicits stronger muscular contractions than on the sound side. This wave of hyperexcitability passes down the nerve from the site of the injury, and is succeeded by diminished excitability, and finally by complete less of power of conduction of the electrical stimuli. Although there may be this complete condition of RD, as described, in nerve and in muscle, yet this does not imply that it is impossible for voluntary stimuli to pass along the nerve and elicit muscular contraction, a condition which may not uncommonly be seen in the recovering stage of nerve injuries and in lead neuritis, in the muscles on the extensor aspect of the forearm.

RD is never met with in the slow muscular atrophy of the myopathies, or in the atrophy of muscle following myositis, unless the nerve elements have been damaged also. In the condition known as **ischæmic myositis** (*see* p. 199), there is no reaction of degeneration found, unless at the same time the nerves supplying the muscle have also been injured. Ischæmic myositis is a condition of primary contracture of muscle due to interference with its blood supply from tight bandaging, or the too tight application of splints. The contracture develops at once, and is thus easily to be distinguished from a paralytic contracture, which takes time to appear. The muscle usually wastes somewhat, but the reactions to faradism and to galvanism will be brisk and of normal character, though probably not so powerful as in the corresponding muscle upon the sound side. In certain cases of ischæmic myositis, as of the flexors in the forearm resulting from tight bandaging or splinting in cases of injury in the neighbourhood of the wrist, the median, or even the ulnar nerve may be damaged by the pressure at the same time as the muscles suffer. In this case there will be anæsthesia, wasting of the skin and nails, and reaction of degeneration in the hand muscles will appear at the end of the first week.

The essential feature of the reaction of degeneration consists in the loss of the faradic excitability of the muscle, while it still retains its contractility to galvanism. When this is the case, the contraction to galvanism is not of the brisk, twitching character seen in normal muscle, and which is produced by the stimulation of the motor nerve-endings in the muscle by the galvanic current when the circuit is closed. Instead, a slow, sluggish contraction is seen, which may be of greater volume than the twitch of the same muscle to the same strength of current in health, but which is more slowly developed and relaxes more slowly. Thus loss to faradism, and preservation of contraction to galvanism, with sluggish contraction, is the essential point, then, of the reaction of degeneration. The polar change, ACC > KCC is not, by any means, always present, and hyperexcitability to galvanism also usually disappears after some weeks. This change, described as reaction of degeneration, is indicative of a lesion of the lower neurone—either sudden, acute, or subacute—damaging the anterior horn cell in the spinal cord, or its axon—the nerve fibre proceeding from the spinal cell to its motor nerve-ending in the muscle. The change seems to be associated with the loss of the fibrillation of the muscle, the sluggish contraction which remains to galvanism recalling that seen in sarcoplasm, or undifferentiated protoplasm, when stimulated by the galvanic current.

As previously said, hyperexcitability to the galvanic current is not always present in cases of nerve injury or damage to the nerve cells in the anterior horn. If the nerve is completely destroyed, as when divided by a stab wound, hyperexcitability to galvanism does not appear. The muscles lose their irritability to faradism after seven or eight days, and at the same time the excitability to galvanism will be found to be diminished, as compared with the normal, though the contractions, when evoked, are sluggish, and the polar change will be present, giving ACC > KCC. This same condition of complete reaction of degeneration will be seen in the worst cases of infantile paralysis, when the nerve cells are completely destroyed; and this absence of hyperexcitability to galvanism, with sluggish contraction and ACC > KCC, may be taken as evidence pointing to a complete destruction of the nerve cells, or severance of the nerve. When the injury is only partial, hyperexcitability to galvanism is usually found, and this sign is thus one of the points of partial RD, with correspondingly better prognosis. This does not seem to apply, however, to facial paralysis, in which, even with the most severe permanent paralysis, with no attempt at recovery or appearance of contracture, there is hyperexcitability to galvanism present, usually for months. It is possible that the facial muscles, being differentiations of the platysma, owe this difference in type of their reaction of degeneration to the fact of their development being distinctive from that of the skeletal muscles.

To sum up: Reaction of degeneration consists of—

1. Loss of contraction to faradism.
2. Preservation of contraction to galvanism, with
   (*a*) Sluggish contraction.
   (*b*) Hyperexcitability.
   (*c*) ACC = or > KCC.
   (*d*) Kathodal or anodal closure tetanus.

Reaction of degeneration may be incomplete—**partial RD,** as it is called—in less severe cases of neuritis or of damage to the anterior horn cells. There are various degrees of partial RD, with corresponding differences in the prognosis as to the severity and duration of the paralysis. Thus, the reaction *to* faradism may be only diminished, and not lost entirely, with a sluggish reaction as compared with the sound side. In the slighter cases the reactions to galvanism may also be reduced, with slight sluggishness of contraction and no polar change. In others, a little more severe, with the reduction to faradism the galvanic reactions may be about normal in strength, or slightly excessive, with sluggishness of contraction especially marked to the anode, while yet remaining brisk to the kathode, while KCC > ACC. Reaction of degeneration is more easily demonstrated in the facial muscles in cases of Bell's palsy, especially in the orbicularis oris, than in any other muscular wasting. Hyperexcitability to galvanism also persists longer in the facial muscles than in any other wasting, being often well marked twelve months after the onset of the paralysis.

The presence of hyperexcitability to galvanism will always be measured by comparing the strength of contraction obtained in the corresponding muscle on the sound side, using the same strength of current. If the muscles on both sides are affected, as in multiple neuritis, then the question as to the existence of hyperexcitability must be judged from experience of the usual strength of contraction obtained from the particular muscle that is being tested with the strength in milliampères, or, roughly, the number of cells that are being used. For example, in well-marked reaction of degeneration in the facial muscles contractions may be obtained to the anode with only two cells, or a current of ½ ma., while normally six to eight cells will be required to obtain a contraction. In the thigh and back muscles, currents of 5 to 8 or 10 ma. are sometimes needed to demonstrate the contraction of normal muscles.

Sometimes a form of partial reaction of degeneration is met with, as in facial paralysis or lead neuritis, in which the voluntary power is only slightly impaired and the faradic reactions of the nerve and of the muscles are but little diminished; while the galvanic reactions of the muscles show the signs of RD above described—especially the sluggish contraction to the anode, which may also give ACC > KCC. Reaction of degeneration does not, therefore, mean always that there is complete loss of voluntary power; for the same thing is seen in the stage of recovery of the nerve, when voluntary power may return in the muscle before any faradic reactions can be obtained and while the galvanic reactions are still sluggish, perhaps hyperexcitable, and ACC either = or > KCC.

Tetany.—This is a condition of muscular spasm affecting especially the distal muscles of the extremities—hands and feet. Slight instances of it are common in the so-called carpo-pedal contractions seen in rickets in very young children. In more severe cases the muscular spasms involve the muscles of the face, back, and abdomen, causing rigidity of expression, slight opisthotonos, and contraction of the abdominal muscles; so that at times there may be some difficulty in separating the disease from tetanus. The flexed condition of the forearms in the spasms, with the interosseal position of the fingers (flexed at the metacarpo-phalangeal, but straight at the inter-phalangeal joints), together with the curious symptom known as Trousseau's sign, will always serve to distinguish the lesser from the grave disease.

As has been said, tetany is common in rickety children, especially when there is much diarrhœa. It is seen in the chronic diarrhœa of tuberculous peritonitis, dysentery, and sprue; in gastric dilatation; in suckling women; after extirpation of the thyroid gland, and sometimes in the course of acute fevers, such as diphtheria. In the severe spasms the pain is intense, though these are not common.

Trousseau's sign is the production of the spasm by firm gripping of the main artery or nerve to the limb—for instance, gripping the arm so as to compress the brachial artery. This pressure probably at the same time compresses one or more of the main nerve trunks to the limb.

Chvostek's sign is the excessive irritability of the facial nerve, so that a quick, light stroke across the skin in front of the ear will produce a sudden contraction of the facial muscles, especially of the orbicularis palpebrarum.

The electrical reactions in tetany are remarkable in that the opening contractions with the galvanic current are obtainable with far weaker currents than in normal muscle. With normal muscles the opening contractions—that is, KOC and AOC—are scarcely obtainable, because the current required is almost too painful to be borne, KOC being especially difficult to obtain. It is said that in tetany the opening contractions may be more easily obtainable than the closure contractions: AOC > ACC or KCC. An anodal opening tetanus has also been described; that is to say, on breaking the current the muscle has been thrown into tetanus at the anode.

It is important to distinguish the reaction of degeneration from that met with in the chronic muscular atrophies due to progressive muscular atrophy or chronic anterior poliomyelitis, idiopathic muscular atrophy, and arthritic atrophy. In **progressive muscular atrophy,** the wasting takes place very slowly, and therefore the faradic reactions diminish gradually, *pari passu* with the galvanic reactions, so that both ultimately disappear when the muscle has completely atrophied. Occasionally, however, in this disease, certain muscles, or parts of muscles, waste more rapidly than others, and then RD, or a partial type of reaction of degeneration, may be seen. In such a case part of a muscle may lose its reaction to faradism and give a slow, sluggish reaction to galvanism, with ACC > KCC, while the rest of the muscle may give a fairly brisk twitch both to the faradic and galvanic currents. In such a case it is possible to observe a double contraction on stimulation of the muscle with galvanism: first, a brisk twitch of the undegenerated part, followed immediately by a sluggish contraction of the part that is degenerating. In the myopathies, or idiopathic muscular atrophy, RD is never seen; but a certain degree of sluggishness of contraction will be observed both to faradism and to galvanism, a condition also seen in arthritic atrophy (*see* p. 149).

In **spastic paralysis,** as in spastic paraplegia due to old myelitis, or lateral sclerosis, or in the rigidity of old hemiplegia, the reactions to faradism and to galvanism will be similarly altered, slightly more difficult to obtain, and more sluggish.

The same change is seen in the muscular reactions when the limb is blue and cold; either from exposure to cold, or in conditions of vaso-motor disorder, as syringomyelia, neuritis, Raynaud's disease and other trophoneuroses. In this condition, which I term the **cyanotic reaction,** the sluggishness of contraction to faradism and to galvanism will pass off at once, and the normal brisk twitch to either current will reappear after a few minutes' soaking of the part in hot water.

Myasthenic reaction.—This is a curious form of reaction usually met with in cases of myasthenia gravis, in which the affected muscles gradually or rapidly lose their excitability to faradism whilst being stimulated; that is to say, their faradic excitability rapidly becomes exhausted. The disease affects adults mostly between twenty and thirty, and its cause and pathology are as yet not understood. There is a progressive asthenia, and many muscles of the limbs, face, and trunk can be rapidly exhausted by repeated contractions, whether voluntary or due to faradic stimuli. When the reaction is well developed the muscle, which responds briskly at first to faradic shocks, soon weakens, until in from three-quarters of a minute to a minute and a half it will no longer contract even to a strong faradic current. Even in this state, if the muscle has been exhausted to faradism only, it will still contract fairly well to voluntary stimuli; and if these be repeated quickly for a similar interval, it becomes paralysed for the time being to voluntary stimuli as well as to faradism. It will still react well to the galvanic current, though no response can be got to voluntary efforts of the patient or to faradic stimuli.

The rapid exhaustion of the muscle to faradism is the essential point of the "myasthenic reaction" which Jolly described in 1895. It has to be distinguished from the reaction of degeneration, which it resembles in the point that the muscle will still respond to galvanism after it has lost all its faradic excitability. The essential point to be recognised is the disappearance of the faradic reactions under observation, and this may occasionally be observed to occur after only a very few single faradic shocks have been sent into the muscle; if these initial responses of the muscle to the faradic current are overlooked, the error of diagnosis of reaction of degeneration will probably be made. The exhaustion of the muscle to faradism and to voluntary effort recovers after a time, if the muscle is left to itself, until it is similarly again exhausted by renewed stimulation.

There is little or no muscular wasting in this extraordinary disease, the symptoms consisting of a variable muscular weakness, on the whole progressive, affecting the face, limbs, trunk, and bulbar muscles. There is almost invariably bilateral ptosis, with a smooth forehead, the usual compensatory wrinkling of the frontalis being absent owing to the weakness of this muscle. The other facial muscles usually involved are the sphincters of the eyes and mouth, the orbicularis palpebrarum and orbicularis oris. Weakness of the lower jaw in chewing, and varying degrees of ophthalmoplegia are also extremely common: Nasal voice, owing to weakness of the soft palate, especially towards evening or after much talking; nasal regurgitation, choking attacks, with paroxysmal attacks of dyspnœa and cyanosis, in one of which the patient may die suddenly, are the usual symptoms, in addition to the limb and trunk weakness.

The myasthenic electrical reaction, although extremely characteristic of the disease, is not absolutely pathognomonic, and it has been described as occurring in many other forms of nervous disease, such as hemiplegia, cerebellar tumour, neurasthenia, and the muscular dystrophies. It was, indeed, first described by Benedikt in 1868 as the "Reaction der Erschöpfbarkeit," ten years before the first case of myasthenia gravis was published. On the other hand, the myasthenic reaction has been found to be absent in undoubted cases of myasthenia gravis.

No lesion of the nervous system has been found to account for the symptoms, the nerve cells and fibres appearing perfectly normal under the closest scrutiny. The only findings of importance have been, in a number of cases, an enlargement or lympho-sarcoma of the thymus, and an infiltration of the affected muscles with lymphoid cells.

CHAPTER V

GALVANISM (*continued*)

Muscular wasting may occur locally from disease or damage to the nerve supply of the muscle. Lesions of the lower motor neurone will be followed by atrophy of the muscle fibre supplied by the neurone, in proportion to the degree of damage to the latter. The lower motor neurone comprises the anterior horn cell in the spinal cord and its axon prolongation, or anterior root fibre, which is continued as the motor nerve to the muscle, ending within the muscle in the end-plate. Lesions of the spinal trophic centre, or poliomyelitis, may be acute, as in infantile paralysis; or subacute, as in some forms of lead palsy; or they may be chronic, as in progressive muscular atrophy. Diseases of the nerves, too, may be acute, subacute, or chronic. Lesions of the upper motor neurone in the brain or pyramidal tracts sometimes cause muscular wasting, as in hemiplegia or in total transverse lesions of the cord. Primary wasting of the muscles may occur in the various forms of the myopathies, or it may result from a myositis due to primary inflammation of the muscular tissue, or from an ischæmic myositis such as may occur from pressure on the muscle from a tight bandage or splint, squeezing out the blood from the muscle and setting up a condition resembling a primary rigor mortis in the living tissue. Arthritic atrophy, again, is reflex to disease of a neighbouring joint, and a certain amount of muscular atrophy also follows after prolonged disuse. In all these conditions, briefly enumerated, the muscular wasting is local, affecting the limb or limbs primarily concerned.

Certain general conditions are also associated with muscular wasting which may be more or less profound; namely, diabetes, cirrhosis of the liver, tuberculosis, pyæmia, rickets, anæmia, starvation, sprue, and in neurasthenia, tabes dorsalis, and Friedreich's disease. In these diseases the muscular wasting is general, and is an expression of defective nutrition and metabolism dependent upon the particular disease with which it is associated. There are certain points of difference in the wasting of muscles, according as it is dependent upon disease of the spinal anterior horn cells, or is due to neuritis, hemiplegia, myopathy, joint lesion, or is dependent upon one of the conditions causing general wasting, such as anæmia or starvation. The diagnosis must, therefore, be accurate, as the treatment and prognosis will necessarily differ in the various groups.

INFANTILE PARALYSIS

Acute anterior poliomyelitis is an acute affection of the anterior horns of the spinal cord, produced by a toxæmia due to one or more forms of microbic invasion. Thrombosis takes place in small vessels in the anterior horns, minute hæmorrhages occur, and, as a result, the motor cells in the anterior horns are damaged and destroyed. The process is, therefore, a very acute one, and the motor nerves supplying the muscles rapidly degenerate, owing to the destruction of their trophic spinal centres. The muscular paralysis is complete from the time of onset of the symptoms. and the limb lies flaccid and the muscles rapidly lose their tone, and waste. Within a very few days those muscles whose spinal centres are completely destroyed will lose their reaction to even strong faradic currents, and will show sluggish contraction to galvanism, and the polar change ACC > KCC. Almost invariably the degree of the apparent paralysis is much greater at first than that which remains as a permanent result; for example, a common type of case is a child of three years who is attacked by an indefinite malaise and feverishness, is kept in bed, and on the next day it is found that both lower extremities are completely paralysed. Yet eventually one of the lower extremities may regain full power, while the other recovers only partially, the anterior tibial muscles and the peronei atrophying more or less completely, and the flexors and calf muscles wasting to a less extent. Not uncommonly all the muscles below the knee may be completely destroyed, and in a few cases (fortunately rare) every muscle in both lower extremities may be completely and permanently paralysed.

Acute poliomyelitis may, though rarely, occur in the adult, and the most severe case I have met with occurred in a policeman, aged forty-eight, in whom there was complete and permanent paralysis of all the muscles of both lower limbs, abdomen, trunk, thorax, and of all the arm muscles, with the exception of the right deltoid, spinati, and biceps, and of the left flexors of the fingers.

After the first ten days or fortnight from the onset of the disease the electrical reactions, taken under an anæsthetic if the patient is a young child, will decide for us what muscles are permanently destroyed, and which are likely to recover and may be improved by treatment. Those which preserve faradic reaction at the end of the first fortnight will eventually recover more or less completely, and their recovery may be often considerably hastened by patient massage and galvanism, applied daily if possible. A flat electrode, 6 inches by 4 inches, well soaked in hot water, should be closely applied to the middle of the back and fastened in position by a bandage, while a moistened disc electrode, 1½ inches in diameter, should be used for the treatment by being rubbed systematically over the muscles requiring treatment. The negative electrode, or kathode, should be used for the treatment, while the anode is applied to the spine. The treatment electrode must be lifted off the skin after each stroke, so as to break the current, as if this is not done the muscle will not contract and the full benefit will not be obtained. The strength of current employed should be, as a rule, about 6 ma.

Another very useful method of treatment is to use reversals of the galvanic current, or voltaic alternatives,

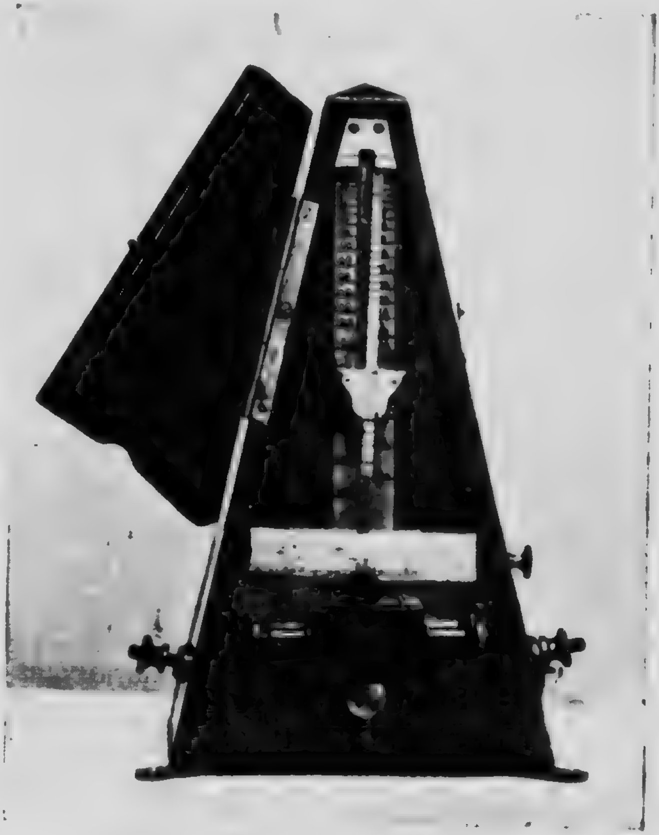


Fig. 12.—Metronome Current Reverser.

as it is sometimes called. If only one limb demands treatment, two flat electrodes are moulded on and fastened to the limb at the two extremities of the part requiring treatment, and the number of cells turned on to give a current of 6 ma., the current being then reversed by turning the current reverser at intervals of about a second. This may be more conveniently done by means of a mechanical reverser, such as a metronome, the spindle of which is prolonged to work a small Pohl's commutator. Such an instrument was made for me by Hoyer, of Wood Green, and has worked regularly for some years in the electrical department at St. Mary's (Fig. 12). The battery current is led on to the commutator, and the electrode wires are fastened to two binding screws connected to the two mercury cups on one side. The pendulum of the metronome is set to beat at the rate of two half-beats in a second, and wound up to continue working for about twenty minutes. If the two lower extremities require the treatment, it is most convenient to have two foot-baths, containing warm water, with one electrode connected to each, one of the patient's feet being placed in each bath. This method is very efficacious, and saves a considerable amount of manual labour, being a necessity in hospital practice.

It is remarkable how cases of infantile paralysis which have been neglected will often improve under steady galvanism and massage, as the muscles which have been only partially damaged often require persistent stimulus before they can be voluntarily used. I have seen a girl of fifteen with severe poliomyelitis, who for six months had been unable to get up out of a chair or to pick up anything by herself, improve so much under this method of treatment, although she could only obtain it twice a week, that she became quite independent of other help. In bad cases the treatment should be persisted in for at least six months, and the massage may be continued with benefit for a year or eighteen months.

POLIOMYELITIS

Subacute poliomyelitis is occasionally met with affecting the muscles of the extremities. It is not very infrequent in cases of severe and recurrent lead poisoning, in which the ordinary form of wrist drop and, perhaps, deltoid paralysis (also from lead neuritis) are prominent symptoms. In these mixed cases of neuritis and poliomyelitis there will be the usual paralysis and wasting of the extensors of the fingers and of the wrist, with escape of the extensor ossis metacarpi pollicis and extensor primi internodii. In addition, atrophy of the intrinsic muscles in one or both hands, most marked in the thenar eminence and two outer dorsal interossei, will indicate an additional poliomyelitis, which usually develops subacutely, the weakness of the hands and the wasting reaching its height in from one to two months, and then becoming stationary. Sometimes in lead poisoning the poliomyelitis may attack the forearm alone without neuritis occurring, and the distribution of the muscles affected may closely simulate the usual wrist- and finger-drop produced by neuritis. The weakness may then be limited entirely to one forearm; and another point of distinction from neuritis will be that the muscles will be affected in groups according to their spinal segmental supply. Thus, in one case the extensors of the fingers, the extensor ossis metacarpi pollicis, the extensor primi internodii, and the extensor carpi ulnaris, were paralysed together on one side, the weakness having gradually developed during two months and remained permanent without any pain or other sensory symptoms. In this case the involvement of the ulnar extensor and escape of the radial extensor of the wrist were the chief clue to the diagnosis of poliomyelitis instead of neuritis, since the radial extensors are supplied by the fifth and sixth cervical segment, and the ulnar extensor, with the extensors of the fingers and thumb, from the seventh cervical.

It is of the utmost importance from the point of view of prognosis to make a correct diagnosis between poliomyelitis and neuritis, because the former condition will be permanent, while the latter will almost certainly recover under proper treatment.

Another common mistake is to diagnose these cases of subacute poliomyelitis [illegible] es of progressive muscular atrophy, recognising their spinal origin, but making the mistake of considering them as chronic progressive anterior poliomyelitis, and therefore of bad prognosis, instead of recognising the subacute nature of the process, which reaches its height in a month or two, and then becomes arrested. In lead poisoning this form of subacute poliomyelitis is not uncommon, and may even affect all four extremities; but true progressive muscular atrophy, causing death, is an extremely rare sequel of lead poisoning, though I have seen it. In the subacute form of spinal paralysis just described the reaction of degeneration on electrical testing of the muscles will not be so well-marked as in cases of neuritis. Thus the faradic and galvanic irritability will diminish almost equally, although the galvanic irritability is always retained longer than the faradic, with sluggish reaction, but giving KCC > ACC.

Treatment of the subacute and chronic forms of poliomyelitis consists of injections of strychnine hypodermically, with massage and galvanism. If the muscles still give fair reactions to faradism, then combined faradism and galvanism may be advantageously employed, or the sinusoidal current may give good results. The same method of applying the galvanism should be pursued as described under the treatment of acute poliomyelitis. If combined faradism and galvanism is decided on, the strength of the galvanism must be less than when used alone, as the addition of the faradism would otherwise be painful. Reversals of 3 to 5 ma. should be used, combined with slowly interrupted faradism. The interruptor of the faradic battery should be so arranged as to give not more than four interruptions per second, and the strength of faradism used should be just sufficient to cause visible contractions of the muscles before any galvanism is turned on. Then, after placing the switch of the combined battery in position for the combined current, or after connecting the negative pole of the secondary faradic coil to the positive pole of the galvanic battery, if two separate batteries are used, the electrode wires are connected to the two remaining binding screws of the two batteries, and the galvanism is slowly turned on. If the two batteries have been properly connected up, the addition of the galvanic current, even without reversals, increases the strength of the muscular contractions which are being produced by the slowly interrupted faradism, so that the contractions due to the faradism, which were previously only just visible, now increase in strength in proportion to the amount of galvanism turned on in addition. This increased irritability of the motor nerves is due to the electrotonic effect of the galvanic current. From 3 to 5 ma. should be sufficient, and the direction of the current should be reversed mechanically about once a second.

This form of current is very convenient and useful to give in arm or leg baths, or with the electrodes strapped on to the limbs, and with a mechanical reverser, such as the metronome. The patient may be left with perfect safety for the required time of the treatment, without the slightest danger of electrolysis of the skin. If, however, the galvanic current is not reversed frequently, there is considerable risk of burning the skin, and quite ugly sore places may be produced. The patient will complain of a feeling of sharp pain and burning, especially as the pad begins to dry, and electrolysis then commences to take place at the surface of the skin instead of in the moist substance of the pad. Re-wetting the pad makes the contact with the skin better, and therefore allows of more current passing, yet it stops the feeling of burning, and the danger of electrolysis of the skin is less. Whenever galvanism is being given continuously without reversals, at a strength of 3 ma. or more, for five minutes or longer, great care should be taken in the adjustment of the pad to the skin, to see that it presses evenly over its whole surface, and that the metal of the pad, or the wire leading to it, is not anywhere in contact with the skin. It is a good plan, too, to take off the pads for re-wetting half-way through the treatment.

On the whole, not much benefit is to be looked for from electrical treatment in subacute and chronic poliomyelitis, whether the galvanic, faradic, or any other form of current be employed. The condition, is, however, so serious a disability to the patient that electrical treatment should always be given a trial, in addition to any other therapeutic measures that may be thought necessary, such as massage, exercises, the administration of strychnine or other drugs.

In subacute and even chronic muscular wasting apparently of spinal origin, between the ages of twenty-one and forty-five, it is a good rule to consider the possibility of syphilis as a cause. Gummatous meningitis, or a gumma damaging the spinal roots in the cervical region, may cause rapid muscular wasting, with severe neuralgic pains, and perhaps weakness of the lower extremities and other symptoms of a spastic paraplegia due to pressure on the spinal cord. The same process may affect the lumbar region, but, more frequently, the syphilitic process manifests itself as a gummatous neuritis implicating the nerves of the lumbar and sacral plexus, causing pain in the lumbar region which may be mistaken for lumbago, followed by wasting of the thigh or leg muscles, and variable degrees of anæsthesia. Biniodide of mercury in sufficient doses in these cases will probably arrest the progress of the disease; and in the majority, unless the process has been allowed to progress too far, the muscles eventually will recover completely. Their recovery may be hastened by employing galvanism and faradism, preferably in the form of the combined current. Syphilis, it is true, may rarely originate a subacute or chronic form of anterior poliomyelitis; in these unfortunate cases no improvement will follow the administration of mercury and iodide, and electrical treatment will also be of no avail.

ARTHRITIC ATROPHY

Is a reflex muscular atrophy occurring in the muscles which are capable of moving a joint or limb that has either been injured, or has become diseased. It is more especially the abductors of the joints which atrophy most, such as the deltoid in cases of lesion of the shoulder joint, and the glutei for the hip joint. This form of muscular wasting is very usually, but erroneously, ascribed to disuse of the limb; but it occurs too rapidly for this, and is often much more marked than disuse could possibly account for. Sherrington has shown experimentally that division of the posterior roots supplying the neighbourhood of a joint, at the same time that the joint is injured, will prevent the onset of arthritic atrophy of the muscles that would occur if the posterior roots had been left uninjured. This means that arthritic atrophy is the result of a reflex process, whereby afferent impulses from the damaged limb or joint travel up to the spinal cord by the posterior roots, and there, by means of collaterals to the anterior horn cells, exert an influence upon the nutrition of these cells, which leads to a certain degree of wasting of the muscles supplied by these cells. If the posterior roots have been destroyed previously to the joint lesion, then these muscles will not waste, owing to the absence of the inhibitory influence of the afferent impulses upon the trophic muscle centres in the anterior horns. Examples of arthritic atrophy are the wasting of the thigh muscles and glutei in hip-joint disease or fracture of the neck of the femur, wasting of the deltoid and spinati in osteo-arthritis or tubercle of the shoulder joint, and of the forearm muscles in osteo-arthritis or tubercle of the wrist.

The faradic reactions in arthritic atrophy are diminished as compared with the sound side, and are slightly more sluggish. The galvanic reactions also show the same changes, the altered reactions to faradism and to galvanism being precisely similar, thus differing from the reaction of degeneration. There will be no tenderness of the muscles, no fibrillary tremors nor anæsthesia:

HEMIPLEGIA

When of organic origin, hemiplegia is usually accompanied by a certain degree of muscular wasting of the limbs on the paralysed side. In some cases the wasting [illegible] so excessive as to suggest some additional neuritis or poliomyelitis, though the absence of any reaction of degeneration will exclude this complication. The wasting is not due to simple inaction of the paralysed limbs, since an equal degree of immobility may be present in functional hemiplegia, in which such wasting does not occur. The atrophy of organic hemiplegia is in some way dependent on the lesion of the upper neurone so affecting the nutrition of the anterior horn cells in the spinal cord, which correspond to the damaged fibres of the pyramidal system above, that the muscles supplied by these trophic centres rapidly waste, *pari passu* with the appearance of spastic rigidity. The electrical reactions will become altered, sluggishness to both faradism and galvanism replacing the normal quick twitch of healthy muscle, and a stronger current will be required to elicit the contractions than on the sound side. There is no RD, however, which is only found in lesions of the lower neurone, either of the anterior horn cells or of the nerves supplying the muscles. That is to say, there is no disappearance of the faradic reactions with preservation and hyperexcitability of the contractions to galvanism, with polar change, ACC > KCC.

A similar condition of muscular wasting of the lower extremities from an injury to the upper neurone is seen in cases of total transverse lesion of the spinal cord due either to fracture, dislocation, or to myelitis. In these cases rapid wasting of the muscles of the lower limbs ensues, with complete flaccid paraplegia, absent knee-jerks, sphincter paralysis, total anæsthesia, and perhaps faint, sluggish extensor plantar reflex. Extreme muscular wasting may occur, yet no RD is seen, the reactions both to faradism and to galvanism being rapidly lost. This wasting used to be ascribed to a descending myelitis involving the lumbo-sacral region of the cord; but this has been shown not to be the case, the anterior horn cells in such cases showing absolutely no changes.

Now, in hemiplegias it is not at all infrequent for joint lesions to be developed, especially in the distal joints of the fingers; though occasionally a large joint, such as the shoulder, may become extremely disorganised by Charcot's joint disease. Joint lesions, therefore, in hemiplegia will be an additional cause of the onset of muscular wasting. Sometimes the periarticular adhesions in these cases cause such extreme pain on movement of the limb that no treatment by massage or electricity is feasible at first. Radiant heat baths may then be of service, and later, light massage. After this has been done for a week or two, electrical treatment by combined faradism and galvanism, as already described, may be advantageously added, and later still, when late rigidity is becoming manifest, the sinusoidal current will be of more service. A frequent question to arise is whether the periarticular adhesions limiting the movement of a joint shall be broken down forcibly and the joint moved under an anæsthetic. Although this treatment may undoubtedly be of the greatest service in the case of joints fixed by local injury or disease, it is far less successful in the case of joints whose fixity is the result of neuritis or of hemiplegia; and, as a general rule, it will be far better to trust to long-continued massage and passive movements, with arthromotor exercises, than to break down the adhesions forcibly. Usually, if this is done, there is considerable swelling and local reaction, with intense tenderness, preventing all movement for some little time, and the adhesions very rapidly form again as densely as before.

NEURITIS

This is an extremely common disease, but the term is one which has been very loosely used, especially by the laity, for all sorts and conditions of muscular weakness and wasting, paræsthesia, and even neurasthenia, that it will be advisable, first, to classify briefly what is meant by neuritis. The term signifies "inflammation of a nerve or nerves," and the process may be either acute, subacute, or chronic. At the same time, the cause of the nerve inflammation may be local, such as the pressure of a crutch on the musculo-spiral nerve, or the exciting cause of the disease may be a toxin acting through the circulation symmetrically on both sides of the body alike, such as alcoholic or diphtheritic neuritis.

Common examples of **local neuritis** are facial palsy, sciatica, brachial neuritis, and injuries to the nerves of the upper limb or brachial plexus, due to pressure, direct violence, etc. Numerous cases of local neuritis are those due to gout or rheumatism ; while rarer forms are tubercular leprosy and ascending or migratory neuritis. Syphilis is a not uncommon cause of local neuritis of the cranial nerves, due to their implication in a gummatous meningitis, and the lumbar or sacral plexus sometimes suffers similarly.

Toxic, multiple, or peripheral neuritis is commonly produced by long-continued overdoses of alcohol, lead, or arsenic ; by diabetes, diphtheria, or septicæmia. Beriberi in the East is a well-known variety, the poison which sets up the disease being probably due to an infection by a bacillus or other form of micro-organism. The mode by which it gains admittance is not known, but two views which have long been held of the etiology of the disease ascribe it either to the rice used as food, or to fish used for diet. Both tubercle and rheumatism are occasional causes of multiple neuritis, though more commonly these causes act locally.

FACIAL PARALYSIS

Facial paralysis is most commonly due to one of two causes: (*a*) chill to the side of the face from exposure to a draught, often during sleep; this type is sometimes called rheumatic, though there is little or no evidence to show that rheumatism plays any part in its production. (*b*) Middle-ear disease.

(*a*) Facial palsy, due to **chill**, may come on within a few minutes of the exposure to cold, or it may be noticed on waking up in the morning or especially after sleeping out in the open. Probably the old superstition, that falling asleep with the moonlight shining on the face produced drawing over of the face, is connected with the observed fact that exposure of the face when asleep at night is often followed by facial paralysis. The condition of the nerve has been stated to be one of degenerative neuritis, most intense at the outer end of the Fallopian canal, and in the peripheral fibres; not an interstitial neuritis, as might be expected. Facial paralysis due to chill is not very unfrequently accompanied by some anæsthesia to light touches of the cheek and forehead, due to the synchronous involvement of the terminal exposed branches of the fifth nerve. The muscular palsy is complete at first, in all except the slighter cases, and involves the upper and lower muscles equally, notably the frontalis and the orbicularis oris, which escape in the supranuclear type of facial paralysis met with in hemiplegia.

The face is thus drawn over to the sound side, the angle of the mouth and the philtrum being displaced by the tonic contraction of the sound muscles. The forehead is smooth on the paralysed side, and all the wrinkles are diminished in prominence. Tears overflow down the cheek on account of the paralysis of the orbicularis palpebrarum allowing the punctum of the lower lid to fall away from the globe; while food collects in the cheek, and the cheek hangs a little and flaps in talking, and the lips cannot grasp the cup in drinking, and saliva is apt to dribble out of that corner of the mouth. Owing to the paralysis of the stapedius muscle, which is supplied from the seventh nerve, hyperacusis may be noticed as a symptom. Loss or diminution of taste, too, is commonly present on the anterior two-thirds of the tongue on the affected side, owing to the involvement of the chorda tympani fibres which run with the motor fibres of the facial in the Fallopian canal as far as the geniculate ganglion, whence they diverge into the pars intermedia Wrisbergi. This loss of taste is usually present in the so-called rheumatic facial palsy, as well as in those cases due to involvement of the nerve from middle-ear disease. In a few instances, however, of rheumatic facial palsy, the taste fibres appear to escape entirely, perhaps owing to the facial nerve being damaged outside its exit from the stylo-mastoid foramen. A certain amount of aching pain, usually referred behind the ear, is very commonly present for a few days after the onset of rheumatic facial palsy, a symptom which may lead to a mistaken diagnosis of middle-ear disease. The amount of the facial deformity is no criterion of the severity of the neuritis, for the face is often pulled over as much at first in the slight cases which may be perfectly well in a month, as in those which take many months before much improvement is noticeable.

The electrical reactions will vary according to the severity of the damage to the nerve. In the slightest cases, such as those which occasionally develop within twenty-four hours of an operation on the mastoid for middle-ear disease, the full reaction of degeneration is not met with. There will be no preliminary stage of hyperexcitability of the nerve to faradism, and the faradic reactions will never be entirely lost, only diminished; while the galvanic reactions will show only a trace of hyperexcitability, and the kathodal closure reactions will always be the stronger, though they will be a little more sluggish and prolonged than the normal. Sometimes this sluggishness of closure contraction will be more pronounced to the anode than to the kathode. In these cases, although voluntary power over the facial muscles is completely lost at first, and the mouth is drawn over to the other side, the tonic contraction of the paralysed muscles returns very quickly, so that even on the next day it may be noticed that there is less deformity, and in a few days scarcely any difference may be seen between the two sides when the face is at rest, although the weakness will appear in acts such as showing the teeth or smiling. By the end of a month there may be no difference detectable even on movement.

It is such cases as this, subsequent either to middle-ear disease or to chill, which make it difficult to believe that a degenerative neuritis is present in all such cases of facial paralysis, as has been described in a few of the fatal cases. If such were so, it is inconceivable how perfect recovery of function could possibly take place in a month; while if the lesion is a perineuritis, as is found in ear disease, causing paralysis by pressure on the nerve fibres contained within the nerve sheath, it would be quite easy to understand how the absorption of the perineuritic or interstitial inflammation of the nerve sheath would set free the fibres from pressure, so that recovery of function might take place completely within a very few weeks. On the other hand, if the lesion were a degenerative neuritis, months would have to elapse before recovery of function could commence, judging by what we know from analogy of the regeneration of other motor nerves, in which five to six months may be taken as a fair average.

The more severe cases of facial paralysis require from three to six months for recovery, and in a large number of them motor recovery is not perfect, although the muscles may recover sufficient tonic contraction to bring the face perfectly straight again, and so hide all the deformity. In the most severe cases, in which the nerve has been completely destroyed, as by accidental division in a mastoid operation, the deformity remains permanent, and no tonic contraction of the muscles takes place. Such permanent and complete facial paralysis is fortunately not very common; even in severe cases sufficient power of conduction along the nerve usually returns to allow of reappearance of tonic contraction of the paralysed muscles, thus pulling the face straight again, and obliterating the deformity, after six months or more, although at the same time no voluntary power whatever over the muscles may be regained. In the more severe cases this tonic contracture becomes overdone, and the face will be drawn over too much, so that at rest the angle of the mouth may be drawn over to the paralysed side, the naso-labial fold will be deeper, and the palpebral fissure partially closed, so that the paralysed side may be mistaken for the sound side, and *vice versâ*.

It is often impossible to say in the early stages whether the case is one of complete and permanent paralysis, in which the nerve fibres are entirely destroyed, or whether a fair degree of recovery may take place. The first sign of commencing recovery will be the return of tonic contraction of the muscles, so that the mouth is less drawn over, and the deformity appears less. This tonic contraction reappears before there is any return of voluntary power over the muscles; and, as I have said, in severe cases the tonic contraction may bring the face quite straight again, though no voluntary power, or scarcely any, is ever regained. In the severe cases, after the lapse of a week to ten days, the fully-developed type of reaction of degeneration will be seen on electrical testing of the muscles. That is to say, there will be no muscular contraction produced on stimulating the facial nerve, either at the stylo-mastoid foramen or in front of the ear, with either the faradic or the galvanic current. Faradism similarly will provoke no contraction when applied directly over the muscles; while there will be hyperexcitability and sluggish contractions to galvanism, the muscles giving definite contractions with a current of 1 ma. or less, with the polar change ACC > KCC.

(*b*) Facial paralysis is by no means an uncommon complication of **suppurative middle-ear disease,** and it may occur in various ways. When facial palsy occurs spontaneously during the course of a chronic otitis media, it is due to a spread of the inflammation to the sheath of the nerve, which has become exposed owing to the advancing caries in the petrous portion of the temporal bone. This form of facial palsy always occurs during an exacerbation of the middle-ear suppuration, and it is always a very severe form of paralysis, little or no recovery occurring. There is generally considerable pain in and behind the ear at the time of its onset; but this is due to the ear disease, and not, as in the rheumatic form, to a synchronous neuritis of exposed portions of the fifth nerve and the cervical plexus.

A common cause of facial paralysis is an **operation on the mastoid** for the chronic suppurative middle-ear disease; and this form of palsy may be of the most severe type, or it may be slight and transient. The most complete and permanent type is due to actual injury to, or division of the nerve at the time of the operation; and it will be recognised by marked twitching of the facial muscles at the time of the injury, which is immediately followed by complete paralysis of that side of the face. There will be found, on testing, complete loss of taste on the anterior two-thirds of the tongue on that side. This is now a rare event in surgery, owing to the frequency with which the operation is practised, and the consequent improvement in technique. A severe type of facial paralysis is also very liable to follow mastoid operations in which a heavy mallet is used. Although the nerve may not be actually touched by the chisel, yet it may suffer from the shock of the blows, which causes hæmorrhage into the sheath of the nerve in the Fallopian canal, thus compressing the nerve.

Perhaps the commonest form of facial paralysis following mastoid operations is that which ensues some hours, or even a whole day, after the completion of the operation. It is obvious that this cannot be due to any injury or compression of the nerve occurring at the time of the operation; but it is apparently due to an inflammatory neuritis of the nerve sheath, possibly sometimes from the action of antiseptics used to syringe out the cavity, or sometimes, perhaps, from slow oozing of blood into the Fallopian canal compressing the nerve. This form of paralysis is the least severe, and is sometimes quite transient, recovery following within two or three weeks, with little alteration of the electrical reactions being noticed. Some cases, on the other hand, which develop several hours to a day after the operation, are more severe, and take some months before the face is practically straight, and even then the recovery is more apparent, owing to the tonic contracture, than a real return of voluntary power.

Facial paralysis sometimes occurs as an event in multiple neuritis, due either to diphtheria or to alcoholic poisoning. Most commonly, when it occurs thus as a symptom in toxic neuritis, the paralysis is unilateral, though occasionally it is bilateral. Damage may occur to the nerve from hæmorrhage in the Fallopian canal or at the base of the brain, or the nerve may be pressed on by tumours in the posterior fossa, such as cerebellar or pontine, or even a tumour growing from a nerve sheath, or the nerve may be implicated in an acute or chronic meningitis, due to tubercle or to syphilis. It is occasionally pressed on by the blade of the forceps during delivery by instruments, the face thus appearing paralysed from birth. In these cases it is often the upper muscles only which suffer; namely, the frontalis, corrugator, and orbicularis palpebrarum.

Intracranial lesions not unfrequently cause facial paralysis. This may be due to the involvement of the nerve in the inflammatory exudate of a meningitis, such as tubercular or syphilitic, or posterior basic; or it may be due to pressure from a hæmorrhage from fractured base, or direct compression of a tumour in the posterior fossa, whether cerebellar, pontine, etc. Indirect pressure from tumours of the cerebral hemisphere, especially of the occipital lobe, occasionally damages the facial nerve.

There is also a form of symmetrical neuritis of the intracranial portions of the two facial nerves, due to syphilis in the secondary stage, that occasionally produces **double facial paralysis**. When this occurs, it is nearly always accompanied by double nerve deafness due to synchronous involvement of the two auditory nerves, causing absolute and bilateral deafness. Double facial paralysis may easily be overlooked, owing to the lack of any deformity of the face. It will be recognised by the absence of facial expression in speaking, the cheeks flapping slightly, and the eyelids never closing, the eyes instead rolling up so as to show the white sclerotics. Testing the facial movements will at once demonstrate the paralysis, total inability to move any of the muscles being then apparent. When this syndrome of double facial paralysis and double nerve deafness is met with, it is a sure evidence in almost every case of syphilis, though I have once seen a case of cerebral tumour in the posterior fossa in which this combination of symptoms was present in addition to other cranial nerve paralyses. Double facial paralysis without deafness also occurs rarely in alcoholic neuritis, diphtheria, or from rheumatism. It is, of course, possible that it may occur from bilateral middle-ear disease, though I have never met such a case. Intracranial lesions of the facial nerve are not accompanied by loss of taste, owing to the separation of the chorda tympani taste fibres from the facial nerve at the geniculate ganglion. The type of muscular paralysis will be of the infranuclear type, just as in those cases due to rheumatism or middle-ear disease.

Nuclear paralysis of the facial nerve may occur from polioencephalitis inferior, an acute inflammatory lesion of the pons of the same nature as acute infantile paralysis. When it occurs, it will cause paralysis of the whole of the face, upper as well as lower. Hæmorrhages or softening at the lower part of the pons, and tumours of this region, may also implicate the facial nucleus on one or both sides. Nuclear palsy will be distinguished from a lesion of the nerve outside the pons by the probable presence of hemiplegia and perhaps hemianæsthesia on the opposite side, and by simultaneous paralysis of the sixth nerve nucleus on the same side, causing paralysis of the conjugate movement of both eyes to the same side. It has often been asserted that some of the facial muscles, the frontalis and orbicularis palpebrarum, have their nuclear origin from the lower portion of the third nucleus, and not from the facial nucleus, the fibres thence passing down the posterior longitudinal bundles to join the facial nerves on their exit. The orbicularis oris was also similarly asserted to be innervated not from the facial nucleus, but from the region of the hypoglossal nucleus. More recent researches, and especially experimental work, have, however, disproved these assertions.

Treatment of facial paralysis.—The common type of "rheumatic" facial palsy is best treated for the first week by fomentations to the side of the face, and keeping indoors with avoidance of all exposure of the face to cold or draught. At the same time, galvanism should be commenced, although there is not any reaction of degeneration present yet. In addition to the fomentations, it is a useful plan to blister the skin behind the ear. The galvanism should be applied by means of two small electrodes, one circular of $1\frac{1}{2}$-inches diameter held close underneath the [illegible] the other $\frac{1}{2}$ inch wide and 2 inches long. This latter is the treatment electrode, and should be stroked over the face, across the forehead, round the eye, and down the cheek along the direction of the fibres of the zygomatici muscles, and then around the mouth on that side. The anode must be used for the treatment electrode, on account of the great sensitiveness of the skin of the face. The anode is less painful than the kathode, and the amount of current necessary for the treatment can thus be better borne. From 3 to 5 ma. should be employed daily, for about fifteen minutes, or, better still, ten minutes on rising in the morning, and again on going to bed at night. Care must be taken that there are no cuts or sore places on the skin to be treated, on account of the great pain the current produces when it touches a raw surface; and for this reason it is advisable for a male patient that the treatment should be given before shaving rather than after. The most sensitive place on the skin of the face is the upper eyelid and above the eyebrow, but 4 to 5 ma. can be usually borne from the anode fairly comfortably. The facial muscles, being really differentiated platysma slips, are very superficial, and for that reason react to smaller currents than are necessary to stimulate the limb muscles.

In many cases, after the first ten days, when the reaction of degeneration is well developed, the hyperexcitability of the paralysed muscles to galvanism is so great that they will react to as small a current as $\frac{1}{2}$ ma. Another peculiarity of the facial muscles is that they retain their hyperexcitability to galvanism much longer than the limb muscles, some hyperexcitability and polar change being often noticeable twelve months or more after the onset of the paralysis.

The treatment by galvanism should be persisted in until the face has become straight again, when it should be left off, in case the tonic contracture that is then occurring should become too marked and so draw the mouth over to the paralysed side. This excessive tonic contracture thus spoils the cosmetic effect which a moderate degree of contracture performs most usefully. After the galvanism is stopped, and indeed for some time previously, as soon as any signs of commencing contracture have become apparent it is a useful plan for facial massage to be given daily after the application of the battery treatment. The patient may very often do this efficiently himself, being taught to rub with the tips of the fingers along the zygomatici and around the orbiculares and over the frontalis. I usually tell the patients to do this two or three times a day when they have a spare five minutes.

Facial Spasm.—Massage to the face is indicated if there are signs of the contracture becoming excessive, and if, in addition to the contracture, there is any clonic facial spasm developed. This is a most distressing and troublesome symptom, and is met with only in those cases of severe facial paralysis in which the resultant contracture has become excessive. Facial massage is the only treatment, any form of electrical treatment being contra-indicated, as it is liable to increase the spasm. Faradism is especially harmful in this respect; and, indeed, the faradic current should never be used at all for facial paralysis under any circumstances. This form of facial spasm does not consist of clonic convulsion of the whole side of the face, but rather of isolated twitchings and fibrillary contractions of various facial muscles. It is when the orbicularis palpebrarum is thus affected that the symptom becomes particularly distressing to the patient. Stretching the nerve has been performed for its relief; this has the temporary effect of reproducing the facial paralysis, but the spasms are liable to return unless—which is not impossible—the facial paralysis on this occasion remains permanent. This form of clonic facial spasm must be distinguished from the clonic fibrillary contractions which occasionally take place in the orbicularis palpebrarum of healthy persons—"live blood," as it is called. This can be often arrested at once by gentle faradism to the muscle for five minutes. Facial spasm due to irritation of the nerve from the pressure of a cerebral or cerebellar tumour, or a patch of softening in the neighbourhood of the facial centre, might also be mistaken for the form subsequent to facial paralysis and accompanying the late contracture, unless the history of the case is carefully gone into.

Facial paralysis due to a supranuclear lesion involving the pyramidal fibres in the pons, crus, internal capsule, or the cortical centre for the face in the ascending frontal convolution, must be distinguished from nuclear or infranuclear lesions, and it does not require any electrical treatment. In the supranuclear type of palsy, the whole face is not equally paralysed, the muscles which are bilaterally associated escaping—namely, the frontales, corrugators, orbiculares oris, and, to a less degree, the orbiculares palpebrarum. The weakness, too, is usually more evident on voluntary movement than on emotional movement of the face; thus showing the gums will bring out the weakness more than an emotional smile.

Occasionally this sign is reversed, and when such is the case it has been said to indicate a lesion in the basal ganglia; but this is not constant. A certain number of cases of complete facial paralysis, usually secondary to middle-ear disease, in which no recovery has taken place after many months, have been treated by nerve-grafting, the facial nerve being divided close to the angle of the jaw and the peripheral portion sutured into a slit made in the sheath of either the hypoglossal or the spinal accessory nerve. A certain number of partial recoveries have been recorded, but others have been made worse (*see* pp. 216, 218).

SCIATICA

Sciatica, or sciatic neuritis, is often most successfully relieved by treatment with the constant current. Sciatica commences as a perineuritis of the sciatic nerve, due often to a spread of inflammation to the nerve sheath from a lumbago, or rheumatic fibrositis. It is a common symptom in the gouty or rheumatic state, and it is not unfrequently acquired directly from sitting on a cold, wet seat. Influenza, typhoid, and sometimes other fevers may leave sciatica as a sequel. Direct injury to the nerve from a penetrating wound is a less common cause.

To be distinguished from sciatic neuritis is sciatic neuralgia, which is a referred pain felt along the course of the sciatic, sometimes for months after the true inflammatory condition of the nerve or antecedent sciatica has passed away. This type of pain may persist in spite of constant rest in bed for many weeks, and although there may be tender spots on pressure along the course of the nerve, there will be no true pain produced by extension of the nerve in the act of flexing the thigh with the knee straight. This form of sciatic neuralgia is not common, but it reacts very quickly to strong galvanism, and I have known such a case which had lasted for eight months after enteric fever, in spite of two months' rest in bed, improve at once with strong galvanism along the course of the nerve, and after a fortnight's daily treatment the pain had entirely disappeared.

Tabetic pains in the thighs and legs may be mistaken for sciatica, though their sudden darting character and symmetry in both limbs should suffice to distinguish them. Similarly the pains of peripheral neuritis, due to alcohol, diabetes, diphtheria, arsenic, etc., may be mistaken for sciatica. Inflammatory growths or tumours in the pelvis may involve the sacral plexus, and thus cause pains resembling sciatica; but usually the extent of the anæsthesia and muscular wasting and weakness will distinguish them from an ordinary sciatic neuritis. Tumours or pachymeningitis in the spinal canal may also simulate sciatica.

The pain of sciatica is very variable in its occurrence. Sometimes it is worst on exertion; but, more commonly, it comes on worse when sitting, or especially when lying in bed at night, often waking the patient up in the early hours of the morning. With some, even violent exertion may cause no pain, although at night it may be severe. Extension of the nerve with the hip flexed and the knee kept straight will cause pain at the back of the thigh and buttock, and the pain is often referred to the back of the knee, or the ankle. Tender spots may be found on direct pressure over the nerve in the middle of the buttock, or in the region of the posterior superior iliac spine. Rarely will there be any anæsthesia of the leg or muscular wasting, though in chronic severe cases these additional signs of neuritis may be present. In the early days of a sciatica there may be an increase of the Achilles jerk, while later it may become diminished, or even lost. The knee jerk of course will not be affected by sciatica. Hip-joint disease, especially the chronic rheumatic arthritis of old people, may cause pain simulating a sciatica; and it is said that the rheumatic inflammation may even spread from the joint to involve the nerve sheath. Undoubtedly it is not uncommon to find the two conditions of sciatica and chronic rheumatic arthritis co-existing in the same patient.

Treatment.—In the early stages of sciatica continued rest in bed is essential, as by that means only can the inflamed nerve be kept at rest. The patient should, moreover, be encouraged to keep the limb as straight as possible in bed, as every time the thigh is flexed tension is put upon the nerve. In order to keep the limb rigidly at rest, some recommend a Liston's long side splint to be applied; but this is usually intolerable to patients with sciatica, and it is better avoided. However, patients with sciatica always find it extremely irksome to remain in the same position for long, especially if, as sometimes happens, the sciatica has been bilateral. For this reason, a water bed will be found exceedingly useful in the treatment of sciatica, as it enables the patient to lie comparatively easily, and he will be less likely to be kept awake by pain. So long as there is any pain at night, and the patient is thus prevented from sleeping, a morphia suppository of half a grain in oil of theobromine should be applied the last thing before "lights out." This method of administering morphia is preferable to hypodermic injection in sciatica, and there will be less risk of setting up the morphia habit in patients of unstable will-power, as it will be much more easy, if necessary, to disguise the fact that morphia is being used at all, to omit all mention of the word, and speak of theobromine suppositories only.

The most effective means we have for controlling the severity of the pain in sciatica, and for arresting the progress of the inflammation of the nerve sheath, is the application of galvanism to the thigh and leg. It must, however, be carefully applied, and the battery must be in good condition and of ample strength. If the following directions are carefully carried out, early disappearance of the pain is to be looked for. The current is to be applied while the patient lies in bed, and two flat plate electrodes of thin lead sheet, covered in front with flannel, with a mackintosh backing, must be used. One should be about 7 inches by 4 inches, the other much larger, 12 inches by 8 inches. They must be thoroughly wetted, and the smaller electrode, after being attached to a wire, is to be placed along the middle of the buttock on the affected side, so that the patient may lie directly upon it. Beneath the electrode must be placed a folded towel to prevent the bed from being wetted. The large electrode is to be folded lengthways around the lower part of the leg and ankle, and in order to make it fit the leg comfortably and keep in good electrical contact, a piece of gamgee tissue or thick layer of cotton wool must be cut rather larger than the electrode and thoroughly wetted and placed inside it next the skin, the electrode then being moulded around the gamgee tissue so as to fit as close as possible. A folded towel or mackintosh must also be placed under the leg to prevent the bed being wetted. The wire attached to the electrode at the buttock is to be fixed to the anode binding-screw of the battery; while the leg electrode is to be attached to the kathode. The current must now be turned on slowly, cell by cell, until from 15 to 20 ma. is registered by the galvanometer, for which strength twenty to twenty-five wet cells will be required, or eighteen to twenty-three dry cells if they are new. This current is to be maintained for five minutes, and then gradually increased by turning on more cells until 25 to 30 ma. are registered; the current being maintained at this level for another fifteen minutes. This treatment should be given twice a day, or even oftener in severe cases if the pain recurs. When the electrodes have been properly coupled up to the battery, they need not be taken off, and the only switch to be moved is the current collector; an intelligent nurse can easily be instructed to apply the electrodes and to turn on a given number of cells, and then to turn off the current after a stated interval. After the first application, the morning and evening treatments should be lengthened to half an hour.

Using an electrode of 7 inches by 4 inches for the buttock, having a surface area of 28 inches, a current of 30 ma. will have a density of only just over 1 ma. per square inch, which is well within the maximum of 1½ ma. per square inch that is safe for the skin for continuous application with ordinary covered electrodes. Even a current of 30 ma. causes a strong stinging sensation which is about as much as the patient can bear for the first ten minutes, but after that the sensation may and usually does get much less, although the galvanometer marks as strong a current. If the cells are new and in good condition, it will be found that the current shown by the galvanometer increases after the first two or three minutes, owing to the more thorough wetting of the skin and consequent diminution of the resistance of the circuit. With thoroughly wetted pads, especially if some saline or soda is used for diminishing the resistance on the pad, the patient's resistance can be brought as low as 2,000 ohms, or even 1,700 ohms. Usually, unless special care is taken to reduce the resistance of the skin, the patient's resistance between two ordinary covered electrodes applied to the skin may be taken roughly as about 3,000 ohms.

In the treatment of sciatica, as described above, I have said that the anode should be applied to the buttock. This is for the reason that the anode is somewhat the more sedative of the two electrodes, and causes less painful sensation to the skin than the kathode. It is not, however, of great importance whether the anode or kathode be applied to the buttock, and the reason for this appears to be as follows. With the two electrodes applied to the buttock and leg as above described, the effect on the sciatic nerve is not the same as if two electrodes were applied to an isolated nerve, when the current would flow along the nerve from the anode to the kathode. In our patient's case the nerve is lying inside the limb at some little distance from the electrodes, and is surrounded by other tissues of equally good conductivity; thus it comes about that only a small fraction of the current passes along the nerve itself, the remainder passing down the limb through the muscles, blood, lymph, etc. In the neighbourhood of the two electrodes, the lines of force of the electric current radiate in all directions into the limb; thus from the buttock electrode some of the lines of force strike the sciatic nerve in an upward direction, and others strike it in a downward direction. Hence there will be a bipolar effect upon the sciatic nerve whether the electrode used at the buttock is the anode or the kathode. (*See* p. 125.)

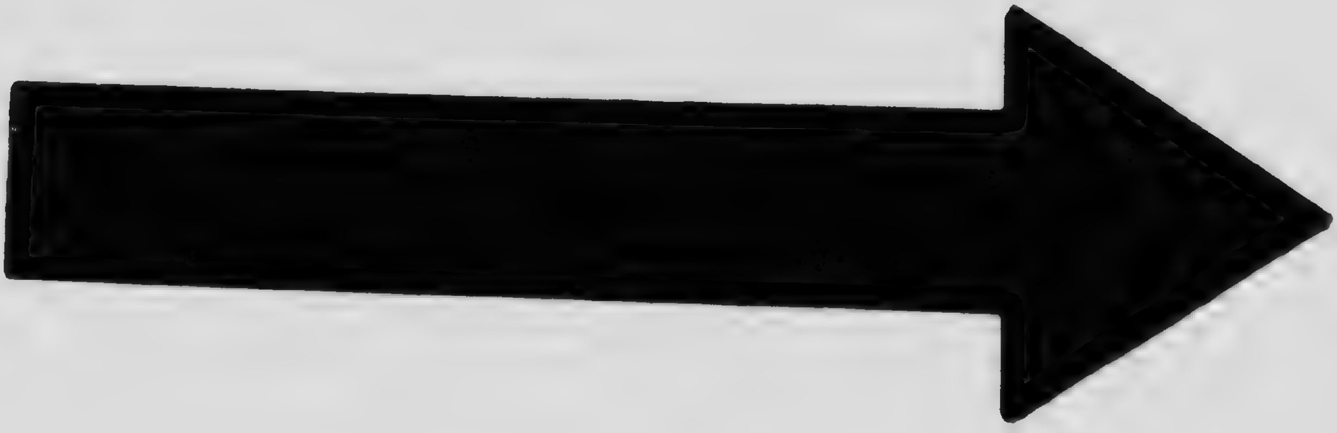
Lately in the treatment of acute sciatica I have been applying the principle of cataphoresis, using salicylate of soda on the buttock electrode. After thoroughly wetting the electrode, powdered salicylate of soda is dusted on the wet surface, using about 1½ drachms of the powder, and the electrode is then placed in position in the usual way. The powdered salicylate is preferable to the flaky crystalline form, as the latter causes more painful stinging for a minute or two when the current is turned on until the crystals are dissolved on the wet pad. When salicylate of soda is thus used for cataphoresis, the active electrode must be the negative or kathode, since it is the ions of the acid salicyl radicle of the salt that it is required to force into the tissues by means of the electric current. It is to be remembered that acids are attracted to the positive pole, and alkalies to the negative pole; therefore, if salicylate of soda be placed on the negative pole the acid salicyl ions will enter the tissues in the reverse direction to the general flow of the current on their way to the positive electrode, while the alkaline soda ions will remain on the kathode pad. Thus, when cataphoresis with salicylate of soda is used in the treatment of sciatica, the negative electrode must be placed on the buttock, though, with the exception of the reversal of the poles, the general directions for the application of the treatment will remain the same.

A point that requires attention is the form of the screw attachment for the wire to the electrode. This should be as low and flat as possible, otherwise the weight of the patient resting upon the electrode makes the screw press that portion of the electrode unduly upon the skin, and tends to produce a sore. The wire leading from the electrode to the battery must be carefully prevented from touching the skin of the patient, if it is covered with cotton, or even silk, as it is so likely to get wet, and if pressed against the skin is sure to produce a sore place. Great care, too, must be taken with the covering of the electrode itself, as after repeated using the flannel is very apt to shrink away from the metal edge, which may then touch the skin and produce an ulcerated wound. The switch must be turned on gradually without producing any breaks of the current, or else the patient will get strong and very unpleasant shocks, and when the required volume of current is obtained the battery should be left untouched until the treatment is ended. For this reason, batteries with a current collector are preferable to the more simple form of batteries known as "Patients'" or "Nurses'" batteries, in which the electrode wires are inserted into the side of the battery—a very insecure fastening, as they are liable to drop out, and when heavy currents are being used as described in the treatment of sciatica, very unpleasant shocks may be given to the patient.

When the time for application of the current has elapsed, the current must not be switched off suddenly, but the collector handle should be turned back slowly to zero before the wires are unfastened. Sometimes the collecting switch does not work smoothly and evenly over the studs, and in this case the current will be interrupted suddenly and shocks will result. If this is found to be the case with the particular battery employed, it will be best to turn on the required number of cells first, and then after applying the electrode at the buttock, to gradually apply the electrode at the leg; similarly, when ceasing the treatment the lower electrode is to be bent flat and the leg gradually lifted out of it. By this method the resistance is gradually diminished or increased respectively, so that the current is applied or withdrawn without any noticeable shock.

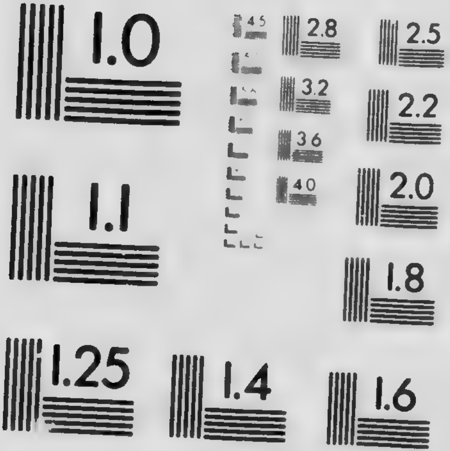
As a rule, improvement is immediate in cases of acute sciatica treated by this method, the discomfort of lying for more than a few minutes in any one position passes off, and especially, the patient will be able to lie upon either side. After the inflammatory stage of the neuritis has subsided, and the pain that remains is mainly neuralgic, then massage to the limb with extensive passive movements of all the joints is of the greatest service in completing the cure. These passive movements prevent the formation of adhesions around the sheath of the nerve, which, if treatment is delayed, drag on the nerve with every movement, and keep up constant neuralgic pain for months or years after the inflammation has entirely subsided. In severe cases, the fibrous adhesions and fibrous tissue in the sheath of the nerve compress the nerve fibres and cause muscular wasting and anæsthesia in addition to the chronic pain, and operation has frequently been successful in relieving this condition by incising the nerve bundles longitudinally and separating the fibrous tissue.

On the other hand, in the early stages of sciatica it is a great mistake to order massage, as then it invariably increases the pain, as is indeed only to be expected when we consider what must be the result of forcible traction and pressure upon an inflamed nerve. It is, therefore, a somewhat delicate and important point to decide at what precise moment it will be safe to order massage and passive movements, as if it is given too soon the patient is thrown back, and if it is delayed too long convalescence may be unduly protracted. The physician must judge by the following points: if the constant pain and discomfort while lying for more than two or three minutes in any one position in bed has passed off, and the patient can lie on his side and flex the thigh in bed without producing pain; if pressure upon the course of the nerve in the buttock and upper part of the thigh does not evoke tenderness; and if it does not produce pain to lift the heel up 18 inches from the bed, keeping the knee straight, then it may be considered safe to commence massage and passive movements. The movements should be free and extensive, being gradually increased in force after the first day, and should be repeated daily. There is often some pain and stiffness pro-



MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No 2



APPLIED IMAGE Inc
1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

duced after the first time, and it will be a good plan to give the galvanism after the massage in order to relieve any pain produced by it.

In some cases radiant heat baths may be used with advantage alternately with the galvanism or massage. The application of blisters down the thigh along the course of the sciatic nerve is also a common treatment, but I have no faith in it and never use it. Nerve-stretching and acupuncture are methods that have been advocated; but personally I strongly disapprove of both. Medicinal treatment by aspirin at first, followed by iodide of potassium, should be persevered with for a fortnight at the commencement of the attack; while convalescence may be completed by a course of baths at Droitwich, Bath, Buxton, or Harrogate.

To sum up, the treatment of an acute sciatica should consist of absolute rest on a water bed, with daily, or twice daily, careful application of a strong galvanic current—especially cataphoresis with salicylate of soda, as described on p. 169; aspirin by the mouth, followed by iodide of potassium, and later, massage and passive movements to prevent adhesions and to break down those in process of formation. Radiant heat baths, with a strong arc light turned on the lower part of the back, are also very useful when the acute stage has passed and the patient is able to get about, but has not completely lost the pain. The full galvanic or hydro-electric bath may now be taken instead of the galvanism to the thigh, as described above.

I may mention here that the Schnée or four-cell electric bath is absolutely useless in the treatment of sciatica; and as sometimes given in hydropathic establishments, with a current of 3 or 4 ma., only brings galvanic treatment into disrepute.

BRACHIAL NEURITIS

Brachial neuritis is the term applied to an inflammation of the various cords of the brachial plexus above the points of emergence from the plexus of the main nerves to the limb, the circumflex, musculo-spiral, median, ulnar, and musculo-cutaneous. Brachial neuritis is commonly of rheumatic or gouty origin. It may follow a direct exposure to cold of the arm and shoulder, but in the majority of cases no such direct cause can be traced. A great many cases of this most painful affection have been seen in the last seventeen years to follow an influenza attack, and the condition is precisely comparable in the upper extremity to sciatica in the lower limb. Occasionally cases arise from the spread of inflammation from neighbouring structures to the nerve sheaths, and I have seen very severe instances of it dependent upon tuberculous adenitis of the neck, tubercular pleurisy, phthisis of the apex of the lung, and septic infection of the wound of an operation in the deep tissues of the neck. Direct injury, too, to the plexus as a whole may sometimes be caused by falls upon the shoulder, though in these cases due to violence, as a rule the motor palsy largely overshadows the sensory impairment—quite the reverse of what obtains in brachial neuritis due to rheumatism, gout, influenza, or the spread of inflammation to the nerve sheaths from neighbouring structures.

Brachial neuritis, exclusive of the traumatic cases, occurs as frequently in women as in men ; and in them the gouty tendency is more likely to be latent than to have shown itself by overt joint inflammations. It will thus constitute one of the possible signs of irregular gout, such as neuralgias, iritis, angina, glaucoma, eczema, and others too numerous to mention here. Indeed, left-sided brachial neuritis may be mistaken for angina pectoris on account of the cardiac distress that may be present as a symptom. This is analogous to the pain that is felt down the left arm and in the side of the neck in angina pectoris, and is probably produced by a reversal of the same mechanism.

Brachial neuritis often commences very acutely, and then the pain in the whole arm may be intense. The pain may be referred at first to various points, such as the back of the shoulder, the forearm, or the inside of the elbow. The pain will be increased on movement of the arm, especially by raising it in abduction ; and there will be persistent tenderness of the nerves on pressure. Even the skin of the arm may become hyperæsthetic as the pain increases. At this stage there is very commonly in the most acute cases considerable swelling of the arm, and œdema of the back of the hand and wrist. The skin of the hand and arm perspires excessively, the temperature of the limb falls several degrees as compared with the other arm, and the limb feels cold and the hand will appear bluish. There will be almost complete inability to move the arm ; but this is due less to actual involvement of the motor nerves by the inflammation and consequent paralysis than to the intense pain caused by all attempts at movement. In the majority of cases, except those due to trauma, there will be little or no wasting, though slight wasting of the whole arm is not very rare. The stress of the disease falls upon the sensory nerves, and the prominent symptom is pain and persistent tenderness of the nerves on pressure, which is increased on movement. The pain, as in sciatica, is often paroxysmal and worse at night, and may therefore be mistaken for neuralgia.

Other trophic evidences of the impairment of sensory nerves are thinning and glossiness of the skin of the fingers, with atrophy of the finger pads, impairment of sensibility to light touches and pin-prick, and lastly, but most important, fixation of the joints due to periarticular adhesions. These adhesions, like the other trophic effects, occur most at the periphery of the limb, and thus it is the interphalangeal joints which suffer most, partial dislocation backwards with considerable distortion taking place in the worst cases. It is the periarticular tissues which suffer from the fibrositis which causes these adhesions and limitations of movement, no new adhesions forming between the articular surfaces. Next to the fingers and wrist, the shoulder joint is apt to suffer most, the elbow usually escaping.

The treatment of these postneuritic joint troubles is most tedious, prolonged massage and careful passive movements, preferably on the arthromotor machine, producing the best results. Breaking down the adhesions under an anæsthetic should be avoided, as, though this treatment appears attractive in theory, the results are disappointing; and often the joints are worse than before, as the forcible straining or rupture of the adhesions sets up anew the fibrositis around the joint, and the pain produced is so severe that practically no passive movements can be borne for many days afterwards, and the adhesions consequently return as before, or even worse.

Treatment.—The treatment of acute brachial neuritis, as of sciatica, necessitates immobility of the limb so long as the active inflammation lasts. This will be determined by the presence of persistent tenderness and pain on pressure over the nerves, and hyperæsthesia of the skin and of the muscles. During this stage the limb should be treated by moist heat, covered over with a thick layer of cotton wool, and fastened to the side in a sling. After a week to a fortnight of this treatment, the pain is probably abating; but drug treatment will help to a certain extent. Aspirin or salicylates and alkalies by the mouth, and probably a nightly injection of one-eighth to one-sixth of a grain of morphia, will be necessary. Some authors recommend injections of cocaine instead, but its anodyne effect is less, and the danger of setting up a drug habit is even greater. Morphia is withheld by some practitioners in practically all circumstances, on account of their dread of the formation of the drug habit, but, properly used, it is the most valuable remedy in the Pharmacopœia, and in the intense pain of severe sciatica or brachial neuritis its use is most certainly indicated during the acute stage. Occasionally atropine or scopolamine may be combined with it advantageously in neurotic subjects. No massage or passive movements of the limb must be allowed so long as the inflammatory stage of the neuritis persists, but galvanism may be employed with benefit as in sciatica, even from the first. It should be given, as in sciatica, by applying the anode to the region of the inflamed nerves and the kathode to the periphery of the limb, but differences in detail will have to be observed.

The anode should be a large circular pad electrode, 3 inches in diameter, and should be applied over a thick piece of flat sponge, or gamgee tissue, rather larger than the electrode, thoroughly wetted with hot water. The kathode should be a large rectangular plate, similar to that used for the ankle in sciatica, and is to be wrapped round the forearm and wrist in the same manner, a piece of thoroughly wet gamgee tissue or cotton wool being laid on the inside of the plate before it is moulded round the forearm. The addition of this extra layer of cotton wool serves two purposes: to prevent undue pressure of the plate electrode upon any bony prominences, and also to hold a sufficient amount of water to insure good electrical contact with the skin during the fifteen to twenty minutes' application of the current; for the ordinary flannel covering of the plate is apt to dry in a short time, thus increasing the resistance, diminishing the amount of current passing, and at the same time producing a sensation of burning; and, indeed, actual electrolysis of the skin may then take place. When this burning sensation occurs, taking off the pad and re-wetting it stops the burning sensation, although more current now passes, owing to the diminution of the resistance between the metal plate and the tissues of the body. When the two electrodes are in position the current should be turned on slowly, and a strength of 10 to 15 ma. may be employed, reckoning the area of the positive electrode as about 9 inches. The current should be applied daily, or twice daily, and a good plan will be to paint the skin above the clavicle where the anode is going to be placed with an anodyne paint composed of equal parts of chloral and menthol, and containing 1 per cent. of morphia hydrochloride. If this is done just before the anode is applied over the spot and the constant current passed, the cataphoretic action of the current will convey the drugs through the skin from the anode, and thus the sedative action of the anode upon the inflamed nerves may be increased by the local action of these drugs upon them. Cataphoresis, with salicylate of soda, using the negative pole, should, however, be tried first, as described in the treatment of sciatica (p. 169).

In favourable cases the pain may have completely disappeared after a few days, but bad cases, especially if treated wrongly with massage and movements at first, may continue painful for many months, and then may leave behind permanent signs of nerve impairment in dulling of sensation, muscular wasting, glossy skin, periarticular adhesions, etc. Neuralgia of the limb may remain, as in sciatica, after the actual neuritis or inflammation has passed away, and then massage and Swedish exercises, tonic treatment, and change of air may be necessary to complete the cure.

BRACHIAL PLEXUS INJURIES

Injuries to the brachial plexus are common results of falls on the shoulder, or of wrenching of the arm, or of fracture of the neck of the humerus. One of the commonest is that known as **Erb's, or Erb-Duchenne paralysis.** Duchenne described this particular form of brachial paralysis in new-born children; it is due to direct traction on the upper roots of the plexus, the fifth cervical root, which is the highest and therefore the most oblique, suffering the most. Sometimes the sixth root suffers also, and in the majority of these cases of birth palsy there is a mass of scar tissue at the outer edge of the scalene muscle involving the junction of the fifth and sixth roots, though it is the fifth root that always suffers the more, as faradic stimulation of the two roots separately will show when the plexus is exposed for operation. The result of this plexus lesion, damaging the anterior primary division of the fifth cervical root, is to cause a pure motor paralysis of a certain group of muscles in the upper arm and shoulder, sensation, as a rule, being entirely unaffected, with no difference to be detected, even on careful testing with cotton wool or pin point.

In a severe case of this fifth cervical nerve lesion there will be complete paralysis of the deltoid, supraspinatus and infraspinatus, biceps, brachialis anticus, and supinator longus muscles, and in some patients—those in whom the plexus is high or prefixed—there will be also paralysis of the pronator radii teres and the two radial extensors of the wrist. These muscles will waste and show the full reaction of degeneration, and in many of the severer cases no recovery takes place, there being permanent inability to raise the arm or to flex the forearm.

When the sixth primary division is paralysed as well as the fifth, there will be weakness of the latissimus, triceps, and pectoral in addition to these other muscles; but usually the serratus magnus escapes, as its nerve leaves the sixth cervical close to the foramen. In more widespread lesions of the plexus, or of the primary nerves which form it, all of the muscles of the forearm and hand may suffer. It is only in lesions of the fifth primary nerve that no anæsthesia is produced; when the sixth is also involved, then there is anæsthesia of the outside of the hand and thumb.

Occasionally partial lesions of the fifth primary trunk occur either from neuritis or as the result of trauma, only the deltoid and spinati muscles being paralysed, the biceps and remaining muscles escaping. This form of paralysis is very difficult to distinguish from a neuritis of the circumflex and suprascapular nerves, which sometimes occurs as the result of direct violence in downward dislocation of the humerus. This accident produces a traumatic neuritis of the circumflex by directly stretching the nerve ; while at the same time the infraspinatus muscle, whose tendon is attached to the greater tuberosity of the head of the humerus, is torn away from the suprascapular nerve, which enters it on its under surface. In this form of neuritis, however, there is more likelihood of the presence of some anæsthesia on the outside of the upper arm than in the case of a partial lesion of the fifth trunk.

Paralysis of the lowest cord of the plexus, the first dorsal, or **Klumpke paralysis,** as it is called, may result from violent wrenches of the arm downwards and backwards, stretching the first dorsal nerve over the first rib as it rises to join the eighth cervical in the plexus.

Sometimes an abnormality is present in the form of a **cervical rib** growing from the transverse process of the seventh cervical vertebra, and then the first dorsal nerve has to rise higher than usual and be bent at a rather sharp angle to reach the plexus. In these cases of cervical rib, which may be bilateral, neuritis of the first dorsal nerve is not unfrequently set up about the age of puberty, with the resultant symptoms of pains in the neck and down the inside of the arm, with numbness and anæsthesia along a strip of the inside of the forearm down to the wrist, and atrophy, of gradual onset, of the intrinsic hand muscles.

Treatment of brachial plexus injuries.—The most severe forms, as a rule, are those in which the upper roots are involved, especially when the fifth root has been damaged, perhaps even ruptured. The main question, then, to decide, if the case is seen within the first few weeks, is whether the roots have been actually torn, and whether operation is required in order to repair the mischief as far as possible by performing primary suture of the torn nerve trunk. It may be taken as an axiom that when a nerve has been divided, the sooner operation restores the continuity the better chance there is of complete regeneration of the nerve taking place, while the longer the period that elapses before the divided ends are brought together the less chance there is of any recovery taking place. Two years is, perhaps, the limit beyond which it is hopeless to expect any recovery from suture of a divided nerve. In cases, therefore, of Erb's palsy, such as those due to falls upon the shoulder in adults, or occurring in new-born children, the question as to whether the fifth nerve has been torn is an anxious question to decide. It is impossible, from the clinical signs of the paralysis, to be sure on this point, either in the first week before any reaction of degeneration has shown itself in the affected muscles, or later. Experience must, therefore, be our guide in these cases, and as it is most rare for the nerve to be actually ruptured in this way, it will be safer to wait three months before considering seriously the advisability of surgical interference. In a certain proportion of cases, although the paralysis may be complete at first, yet the injury to the nerve has not been severe, and though slight reaction of degeneration appears on electrical testing after the first week, yet voluntary power soon commences to return, and complete recovery may ensue in from one to three months. In more severe injuries, there may be well-marked reaction of degeneration, yet signs of recovery may appear after eight or ten weeks, with eventual complete return of power after eighteen months or two years.

The only cases in which operation is certainly indicated from the first are those in which the arm has been paralysed from a stab wound in the neck, or in which, as the result of a severe fall, there is paralysis of the lower limbs in addition to the paralysis of one or both arms, which may resemble the type of Erb's paralysis. In the former case it is practically certain that one of the nerves of the plexus has been divided by the knife wound; while in the latter there has been fracture dislocation of the sixth cervical vertebra, and there is almost certainly pressure being exerted upon the spinal cord by a piece of bone, removal of which by laminectomy may completely cure the patient.

Meanwhile, the paralysed muscles should be treated daily with galvanism by the labile method, the indifferent electrode being a flat plate placed behind the neck, while the treatment electrode (in these cases the kathode) is a round disc 2 inches in diameter, attached to the usual form of handle. Massage, too, should be employed and the limb supported in a sling, care being taken as far as possible that the paralysed muscles should not be allowed to remain in a constant position of passive extension. Paralysed and wasted muscles are much more likely to recover, and do so in a shorter time, if their attachments are kept approximated. Thus, in the case of a paralysed biceps the forearm should be kept at a right angle, and in the case of dropped wrist the hand should not be allowed to hang in that position, but the wrist should be kept constantly extended by a light splint, or similar apparatus. For dropped wrist I find the following apparatus sufficient: an ordinary leather wrist strap is buckled round the wrist, and a strong, broad piece of tape is sewn in a loop around the second, third, and fourth fingers. A broad piece of flat elastic is fastened by its two ends to the tape and to the wrist strap, its tension being so graduated as to exert a constant pull in extending the wrist.

It is, however, practically impossible to treat the deltoid muscle in this way, owing to the difficulty of keeping the arm constantly abducted. This is the only muscle which raises the arm, the clavicular portion of the pectoral having only an adductor action on the arm when it is held straight out in front. The contraction of the latter muscle prevents the natural action of the deltoid acting alone, which would sweep the arm outwards and away from the middle line. The supraspinatus muscle assists the deltoid very slightly in raising the arm, also rotating the humerus inwards; but this muscle is almost invariably paralysed at the same time as the deltoid, as, although they are supplied by two different peripheral nerves, yet both the deltoid and the spinati, supra- and infra-, receive their motor fibres from the same primary nerve of the plexus, the fifth cervical. Sometimes these three muscles are paralysed together from a partial neuritis of this uppermost nerve of the plexus, from direct *exposure of the neck to cold*, the onset being marked by considerable pain in the neck and shoulder. The prognosis in these cases is usually good, though many months, often a year, may elapse before the deltoid regains much of its power. Persistent massage and galvanism will, however, aid their recovery considerably.

Serratus magnus paralysis may be the result of a similar neuritis of the long thoracic from exposure to cold, or from the pressure of a heavy weight, such as the corner of a heavy box pressing above the clavicle when carried on the shoulder. Another cause of serratus magnus palsy is violent muscular action of the scalenus medius, through which the long thoracic nerve runs. This form of paralysis I saw in a young man who developed sudden paralysis of the serratus magnus while using the side stroke in a swimming race. The onset of neuritis of the long thoracic is accompanied by a good deal of pain above the spine of the scapula and along its vertebral border, which may persist for many weeks. I do not consider this neuralgic pain a contra-indication to treatment of the paralysed muscle with galvanism.

The **posterior scapular nerve** may suffer in a similar way, causing paralysis of the rhomboids, the levator anguli scapulæ, and the upper portion of the serratus magnus, and often the middle and lower fibres of the trapezius. This grouping of paralysis I have seen as the result of muscular strain in a labourer who was heaving earth out of a deep ditch up on to the bank over his left shoulder. At the end of a strong effort he felt a sudden shooting pain in the left side of his neck and at the back of his left shoulder, which was at once followed by weakness of the limb, so that he had to give up his work. He ultimately recovered completely under treatment by massage and galvanism.

Trapezius paralysis.—*See* under Cranial Nerves. pp. 215-18.

MUSCULO-SPIRAL PARALYSIS

This is one of the commonest forms of nerve paralysis of the upper extremity. Owing to its winding course round the humerus close to the bone it is peculiarly exposed to pressure, and the two most frequent causes of its damage in this way are pressure by a crutch, and pressure during sleep, either by the weight of the head upon the arm, or by the arm hanging over the back of a wooden chair. This form of nerve paralysis has been named "Sunday paralysis," owing to its occurrence in frequenters of public-houses sleeping off the effects of a Saturday night debauch in a wayside ditch, or in a wooden chair with the arm thrown over the back of it. The pressure of a crutch in the axilla compresses the nerve against the humerus higher up than when it is injured during sleep or anæsthesia, and it is owing to this reason that in the sleep palsy of this nerve the triceps usually escapes, while in musculo-spiral palsy due to the pressure of a crutch the triceps is usually weak. The most obvious result of the nerve lesion is dropped wrist, there being complete inability to extend either the wrist, fingers, or thumb. The supinator longus is paralysed in addition to the extensors in the forearm, while in lead neuritis the supinator longus, the extensor ossis and primi internodii pollicis escape. This difference in the extent of the palsy makes it easy to differentiate lead paralysis from musculo-spiral paralysis. In the latter there is generally at first some numbness over the back of the thumb, index and middle fingers, and the outside of the back of the hand, as far down the fingers as the first interphalangeal joint, where the supply of the radial nerve joins that of the median. There will be partial tactile anæsthesia and analgesia over this area for the first few weeks, the loss of sensation usually disappearing before the return of voluntary power.

Musculo-spiral paralysis sometimes occurs in alcoholic subjects during the day while the patient has been awake, and without any obvious cause of pressure. It is difficult to understand how this occurs, for if the paralysis were due to the action of the circulating toxin on the nerve, the effects should be bilateral and symmetrical. Possibly in all these cases there is some slight trauma which escapes notice, the nerve being on the brink of neuritis on account of the patient's alcoholic habits. Occasionally the nerve may be damaged by being torn by the sharp edges of the bone in fracture of the humerus, in which case, of course, the paralysis dates from the moment of the accident; or the nerve may be implicated later in the callus formed during the healing of a fracture of the bone. A stab wound in the upper arm may similarly sever the nerve, and forcible contraction of the triceps has even been said to produce a traumatic neuritis of the musculo-spiral. Whatever its cause, musculo-spiral paralysis is of sudden or almost sudden onset, and for this reason and because the muscles supplied by it in the forearm are not covered with a thick layer of tissue as, for instance, the hamstrings are, the reaction of degeneration is very pronounced in the extensor muscles in the forearm in cases of musculo-spiral paralysis. In the most severe lesions of the nerve, as when the nerve is actually divided by a stab or a bullet wound, the hyperexcitability to galvanism that is generally seen in ordinary cases of crutch or sleep palsy is absent, and the form of the reaction of degeneration that is found is complete loss of faradi reactions, with diminution of excitability to galvanism and very sluggish contractions. Powerful currents are required to evoke the contractions, and within a month of the division of the nerve the contractions may be only visible on reversing the direction of the current suddenly, while the plain make and break of a current of 10 ma. may cause scarcely any contraction. Moreover, the contractions at the anode do not show the usual excess over the kathode for very long; for when after a few weeks a strong current is necessary to evoke the contractions, the kathode closure contraction is then usually the stronger, KCC > ACC.

In the cases of moderate severity there will be also complete faradic loss after ten days, but there will be marked hyperexcitability to galvanism, a current of 1 to 1½ ma. producing distinct contractions, sometimes brisker to the anode, sometimes to the kathode, though there is never as much difference between the strength of the KCC and ACC as with a normal nerve and muscle. Not unfrequently the contraction to the anode is more sluggish than to the kathode, though the amplitude of the contractions may be about equal.

Treatment.—In the treatment of musculo-spiral lesions our chief concern will be the re-establishment of motor power, since the sensory impairment is never very deep or troublesome, and pain is either trifling or absent. If the wrist-drop is complete at first, with no voluntary power in the supinator longus or any of the extensors of the wrist, fingers, or thumb, it will be a difficult matter to decide until a fortnight has elapsed whether the lesion is a complete division of the nerve or one of only moderate severity. With the establishment of the reaction of degeneration a further clue will be obtained, as those cases where the hyperexcitability to galvanism is most marked will not turn out to be cases of complete severance of the nerve. The presence of definite anæsthesia over the distribution of the radial nerve on the outer side of the back of the hand, fingers, and thumb, as high as 3 or 4 inches above the wrist, will be an additional evidence of a severe lesion of the nerve, as definite anæsthesia over this area is often absent in slight cases of musculo-spiral paralysis, which recover quickly.

Since the nerve is rarely the seat of a rheumatic or gouty perineuritis like sciatica, with pain as a prominent symptom, it will be unnecessary to treat the case with prolonged rest, for the lesion in the large majority of cases is not an inflammatory one, but merely a crush of the whole nerve, the motor nerve fibres especially being damaged. An extension apparatus for the wrist, as described above (p. 181), should be worn, and the extensor muscles in the forearm should be treated by galvanism daily by the labile method, and also well massaged. The principle of the treatment will be to keep the muscles as far as possible in good condition pending the recovery of the nerve; but the recovery of the nerve fibres will depend upon the degree of the damage, and little can be done to hasten their recovery. With a severe crush, little or no voluntary power over the extensors may return for four to six months, and full power will not be regained for eighteen months to two years. The large majority of sleep and crutch palsies are, however, less severe than this, some degree of power returning at the end of a month.

The galvanism will be best applied by wrapping a large flat electrode round the arm above the elbow, and using a round disc electrode, 1½ inches in diameter, for the treatment electrode. The kathode should be used for the treatment, from 5 to 10 ma. of current being employed, according to the strength of contractions obtained. In the slighter cases in which the muscles do not entirely lose the faradic reactions, and also in the severer forms in which recovery is commencing and the faradic reactions are returning, it is a good method to use combined faradism and galvanism for the treatment instead of galvanism alone. It is best not to use rapid interruptions for the faradism, but to use a means of interrupting the faradism slowly, about two or three times a second, such as an aluminium weight fixed on to the Wagner hammer. By using this mechanism the muscles are not tetanised by the faradic current, but are able to relax after each contraction. Better results will be obtained by that means than by using either current alone. The strength of the faradism to be employed in this combined method must be ascertained by testing the muscles first with single faradic shocks, obtained by working the interrupting hammer by hand. When this is done, it will be found that when the secondary coil is pushed sufficiently near to the primary, muscular twitches are produced by thus interrupting the battery current; while practically nothing is felt at the make of the current, even when the break current is too powerful to be borne. The strength of the break faradic shocks should be so adjusted that, before turning on any of the galvanic cells, weak but distinct muscular twitches are produced. Then, turning on the galvanism, a strength of 5–7 ma. should be employed, the addition of which, by setting up a condition of katelectrotonus in the nerve, increases the excitability of the nerve so that the faradic shocks now produce stronger contractions.

This combined current may either be applied by the labile method as described above, or two flat electrodes may be strapped on to the arm, one round the wrist and the other above the elbow, while the galvanic current is reversed regularly about twice a second. The reversal of the current may either be performed by hand with the current reverser on the battery, or a special reverser may be employed, such as a metronome driving a Pohl's commutator (p. 143). The combined current is most easily obtained from a combined battery containing both the galvanic and faradic apparatus, with a De Watteville switch for using either the faradism or the galvanism from the same pair of binding-screws. For obtaining the combined current, the switch must be placed in the middle line, half way between F and G.

Some authorities recommend the sinusoidal current for the treatment of muscular wastings. In my opinion, the ordinary sinusoidal current, or alternating current obtained from the electric lighting alternating current mains, is far too rapid in the period of its alternations, which varies according to the dynamo used in the installation from about 40 to as high as 110 per sec. This rate of alternation is as rapid, or even exceeds the speed of, a fast working hammer of a faradic battery, and as a result the muscles are tetanised, which is, I consider, not desirable. Dr. Morton has designed an alternating current dynamo to work at a periodicity of only two or three cycles per second, and he claims good results for this method of treatment. The machine is made by Messrs. Schall, and the type of current somewhat resembles that of a galvanic battery working with slow reversals as described above ; but the changes in the electromotive force are much more smooth and less jerky, and thus are less efficient in producing muscular contractions.

ULNAR NERVE PARALYSIS

Like musculo-spiral palsy, ulnar nerve paralysis may be the result of pressure upon the nerve during sleep. Either of these nerves, moreover, may be damaged by pressure due to a prolonged strained position of the arm while an anæsthetic is being given. The name *postanæsthetic* paralysis has been given to this form of nerve lesion, and in this way one or more of the branches of the brachial plexus may be sometimes damaged. The ulnar nerve may be damaged by a blow upon the elbow, or by fracture of the humerus at its lower end, by a stab wound, or by inclusion of the nerve in callus as the result of fracture in the neighbourhood of the elbow joint.

Perhaps the most common cause of injury to the ulnar nerve is a wound cutting across the front of the wrist. This is very often the result of putting the hand forcibly through a pane of glass, or of a slash from a knife. When the nerve is thus divided, it is most important that the surgeon who first sees the case and sews up the wound should be careful to look for the two ends of the divided nerve and sew them together; for unless this is done a permanently clawed and useless hand is almost certain to result.

With such an injury it is most important to test the sensation of the fingers so as to decide whether or not the median or ulnar nerve has suffered. The ulnar nerve takes its origin from the inner cord of the brachial plexus, and therefore derives nearly all its fibres from the eighth cervical and first dorsal roots. In a low or post-fixed plexus it is possible that the second dorsal may send into it some motor fibres for the interossei, and in a high or pre-fixed plexus the nerve gets a very definite bundle from the seventh root carrying motor fibres to the flexor carpi ulnaris. The nerve gives no branch in the upper arm, where it is fairly well protected from injury until it winds round the inner condyle to enter the forearm between the two heads of the flexor carpi ulnaris. In the forearm the ulnar nerve supplies this muscle and the inner half of the flexor profundus digitorum by branches arising near the elbow; thus, wounds of the ulnar nerve above or at the elbow will paralyse these muscles, while if the nerve is damaged in the middle of the forearm or below, the flexor carpi ulnaris and profundus digitorum will escape. In the former case the wrist will be abducted somewhat on clenching the fist, and there will be inability to flex the terminal phalanges of the little and ring fingers.

The dorsal cutaneous branch arises from the ulnar about two inches above the wrist, and passes backwards to supply the dorsum and sides of the little finger and inner side of the ring finger. Hence, a wound at the wrist dividing the ulnar nerve below the point at which the dorsal cutaneous branch is given off, will not cause anæsthesia of the dorsum of the little and ring fingers, but only of their palmar surfaces. At the wrist the nerve gives off the muscular branch which passes deeply between the abductor and flexor brevis minimi digiti muscles, and then along the course of the deep palmar arch beneath the flexor tendons, supplying the hypothenar muscles, all the interossei, the inner two lumbricals, the adductor pollicis, and the inner half of the flexor brevis pollicis. This branch is, therefore, a purely muscular branch, and it may be wounded by a fall on the wrist and hand on to a sharp piece of glass or a spike. In this event, the muscles above enumerated will waste, but there will be no anæsthesia produced. As a result of the muscular paralysis of the interossei and the two inner lumbricals the hand will assume the clawed shape, the first phalanges being retracted and the two distal phalanges partially flexed, the two ulnar fingers being the more affected. The hypothenar eminence will appear wasted, and there will be hollowing between the thumb and index finger on the dorsal side, owing to the atrophy of the first dorsal interosseus muscle, while the outline of the metacarpal bone of the index finger will be prominent. The thenar eminence will not be wasted, owing to the preservation of the abductor and opponens pollicis, but there will be hollowing between the thenar eminence and the palm of the hand on account of the atrophy of the adductor pollicis and inner head of the flexor brevis pollicis. The terminal or superficial palmar branch of the ulnar is almost entirely a cutaneous branch, supplying only the palmaris brevis muscle in addition to the integument on the inner and palmar side of the hand, the little finger, and inner half of the ring finger. This terminal branch may be injured alone, with resulting anæsthesia on the palmar and inner side of the hand and no muscular paralysis, or it may be divided in addition to the deep muscular branch by the same injury at the level of the wrist.

In some persons the ulnar nerve is constantly pressed upon in its passage round the internal condyle in every act of flexion of the elbow; an ulnar neuritis may be thus set up, causing pain and tingling along the distribution of the nerve. It is quite common for many people to notice after leaning on one elbow for several minutes that the inner side of the hand and fingers has "gone to sleep," with weakness in straightening the two inner fingers. This is due to a temporary paresis of the ulnar nerve by being stretched. The same condition continued for a longer time, as when asleep or under the influence of an anæsthetic, will cause a pressure, or sleep palsy, of the nerve.

Ulnar paralysis is to be distinguished from lesions of the inner cord of the brachial plexus or of the eighth cervical and first dorsal roots, and also from spinal lesions at the level of the first dorsal and eighth cervical segments. The former will be recognised by the distribution of the muscular paralysis and anæsthesia differing somewhat from that of ulnar palsy. Moreover, in most cases the approximate site of the lesion will clearly determine whether it is the inner cord or the ulnar nerve that has suffered, although, since the ulnar nerve gives off no branch from the point of its formation until it enters the flexor aspect of the forearm, a lesion of the nerve at its point of origin from the inner cord and also at the bend of the elbow will produce precisely the same symptoms.

Since the inner cord gives off the inner head of the median as well as the ulnar nerve, a lesion of the inner cord will cause more extensive muscular paralysis than an ulnar lesion. All the intrinsic hand muscles will now be wasted, with the superficial and deep flexors of the fingers, the long flexor of the thumb, and the flexor carpi ulnaris. When the inner cord is damaged near to its formation by the union of the eighth cervical and first dorsal primary divisions, there will be, in addition, weakness of the sternal portion of the pectoral muscle, through implication of the internal anterior thoracic nerve, anæsthesia of a strip along the inside of the forearm due to the internal and lesser internal cutaneous nerves, and also weakness of the extensor indicis, minimi digiti, and secundi internodii pollicis, due to implication of the posterior division of the eighth cervical and first dorsal nerves which joins the musculo-spiral.

Sometimes the first dorsal root alone may be damaged by a wrench of the arm downwards and backwards stretching the nerve over the first rib. This lesion will simulate an ulnar palsy in causing wasting of the intrinsic musculature of the hand; but the thenar muscles escape in ulnar palsy. The anæsthesia, too, will differ—that in ulnar palsy involving the little finger and inner half of the ring finger; while a lesion of the first dorsal root produces a strip of anæsthesia along the inner side of the forearm as far as the wrist, and does not include any part of the hand. In certain cases it is possible for the first dorsal root to be injured within the spinal canal close to the cord, when, in addition to the above symptoms, there will also be paralysis of the sympathetic pupil-dilator fibres, so that the pupil will remain medium small, and will not dilate in shade.

Treatment.—The treatment of lesions of the inner cord or of the ulnar nerve will be on the same general lines as in musculo-spiral paralysis, though, as there is no wrist-drop, there will be no necessity for any extensor splint apparatus. When the lesion to the ulnar is low down at the wrist, a good arrangement for the electrode is to place the hand flat, palm downwards, upon a flat disc electrode, while another disc electrode is laid upon the back of the hand. Galvanism should be employed, and the current reversed at a rate of from once to twice a second, the strength of the current being from 5 to 10 ma., according to the strength of the contractions obtained. Faradism will be of less use in the treatment of ulnar palsy, though when the faradic reactions are commencing to return, the combined current with slow faradic shocks may be given.

The prognosis in ulnar palsy depends, of course, on the severity of the lesion, slight injuries, as from pressure during sleep, usually commencing to improve within a fortnight.

It is in the cases of division of the nerve near the wrist that there is especial danger of the nerve remaining permanently paralysed, for the surgeon's attention is very likely to be more specially directed to picking up and reuniting divided tendons than to examining the condition of the ulnar nerve; and it is often not until some days afterwards, when the patient is becoming more accustomed to the wound, that the loss of sensation over the ulnar distribution is noticed, and the discovery made that the ulnar nerve was divided at the time of the injury. Reopening of the wound is now necessary, and secondary suture of the divided ends of the nerve must be performed. This late suture of a cut nerve is much less likely to be successful in entirely restoring its functions than is a primary suture, and recovery is still less likely to ensue should the wound have suppurated. Even under the most favourable circumstances, if the nerve has been divided, complete return of perfect sensation and motor power is scarcely to be looked for under twelve months, though certain forms of sensation recover earlier than others.

Head has shown that peripheral sensation consists of three separate forms: (1) *Deep sensibility*, or sensations of pressure, which may be actually painful, and which are perceived by the muscles, tendons, and deeper structures through the medium of sensory fibres running with the motor nerves to the muscles; (2) *protopathic sensation*, or sensations of pain to pin-prick, etc., including recognition of extremes of temperature of heat and cold; (3) *epicritic sensation*, or finer sensations of touch, including accurate localisation, and recognition of milder degrees of warmth and coolness. Of these, the third does not overlap in its peripheral distribution, while protopathic sensation and deep sensibility do overlap considerably in the distribution of neighbouring peripheral nerves. For example, in the case of a divided ulnar nerve, epicritic sensation will be lost over the inner side of the hand and the little finger and the inner half of the third finger, corresponding accurately with the anatomical distribution of the nerve, while sensation to pin-prick will be only partially lost on the inner half of the third finger, but completely lost on the little finger; deep sensibility, also, will be but little impaired on the third finger.

These different forms of sensation do not recover simultaneously after suture of a divided nerve, epicritic sensation taking very much longer than the protopathic. The latter, in a favourable case, may commence to return in six weeks, and be completely recovered in ten weeks, after which the liability to trophic sores disappears. Motor recovery does not commence until from five to six months after suture, and may take twelve to eighteen months before completion, while epicritic sensation does not commence to return until ten months have elapsed, being complete in about twelve months. Occasionally, especially after secondary suture, protopathic and deep sensibility recover, while at the same time there is no return of epicritic sensation or of motor power, the muscles remaining permanently wasted. For the hand, it is much more important for the patient to get return of a fair degree of sensation than that the intrinsic muscles of the hand should recover; for if there is deep anæsthesia of the little finger and inner side of the hand, the value of the hand is very considerably impaired as a sentient and prehensile organ, as the little finger will be constantly getting in the way and be in danger of injury, while at the same time there will be great difficulty and, indeed, impossibility of recognising objects by the touch. If, however, protopathic sensation and deep sensibility return, it will make a considerable difference to the usefulness of the hand, even though the interossei remain permanently wasted.

MEDIAN NERVE PARALYSIS

Like paralysis of the ulnar nerve, that of the median nerve may result as part of a brachial plexus lesion, or it may be injured in the axilla, arm, or forearm. Like the ulnar, it gives no branch above the elbow, entering the forearm between the two heads of the pronator radii teres, which it supplies. In the forearm it gives off muscular branches—the anterior interosseous and the palmar cutaneous. The median nerve receives fibres from all the five roots that enter the brachial plexus, and it conveys motor fibres to all the flexor muscles in the forearm except the flexor carpi ulnaris and the inner half of the flexor profundus digitorum, which are supplied by the ulnar.

The *outer head* of the median carries the motor fibres for the pronator radii teres, the flexor carpi radialis, palmaris longus, and a few fibres to the flexor sublimis digitorum, while at the same time it also carries sensory fibres to the skin of the palm of the hand, the thumb, and outer three fingers. The *inner head* of the median carries the motor fibres for the major portion of the flexor sublimis, the flexor longus pollicis, the outer half of the flexor profundus, the thenar muscles, and the two outer lumbricals, but no cutaneous sensory fibres. Like the ulnar, the median nerve supplies part of the dorsum of the fingers, the terminal two phalanges of the index and middle fingers, and the outer half of the dorsum of the terminal two phalanges of the third finger.

Treatment.—The treatment of median nerve paralysis will be on the same lines as ulnar paralysis. The nerve is liable to injury in the upper arm from stab wounds, but never suffers, like the musculo-spiral, by compression against the bone. In the forearm it may suffer from pressure on the flexor aspect, especially during sleep, or from the pressure of a tight bandage or splint; but it is less common than ulnar paralysis from this cause. Stab wounds and gashes across the wrist may divide the nerve, and sometimes it is involved in scar tissue, although the nerve may not have been injured at the time of the original wound. In this latter case the patient will complain of tinglings in the thumb and two outer fingers, with occasional pain, which is evoked or increased by pressure over the site of the scar.

I have seen a case of partial median nerve paralysis thus produced by a slight amount of scar tissue in the upper part of the forearm, the result of a stab wound several weeks previously. There was slight but definite anæsthesia to touch and pin-prick over the cutaneous distribution of the median, with weakness of the muscles supplied by it, and also very definite diminution of the briskness of these muscles to the faradic current, though there was no hyperexcitability to galvanism or polar change. The wound was reopened and the scar tissue dissected off, with the result of almost immediate return of power. Careful testing on the morning following the operati onshowed that the grip was now much improved, and there was scarcely any detectable anæsthesia. Moreover, I took the faradic reactions again, and found that the briskness of reaction of the flexors to faradism was now much increased, much more like those of normal muscles. The man, an artisan, declared that he found his hand was much stronger and less numb as soon as he came round from the anæsthetic. The operation had disclosed two rings of thin scar tissue surrounding the upper part of the median nerve in the forearm, but the nerve did not appear to be nipped there or at all narrowed. This case is evidence that it is possible for actual muscular weakness, partial anæsthesia, and diminution of faradic excitability to result from very slight compression of a nerve without any destruction of the nerve fibres. Apparently the compression of the scar tissue was sufficient partially to obstruct the conduction of both motor and sensory impulses along the median nerve, without damaging the fibres enough to set up degeneration, so that removal of the compressing scar tissue was followed by immediate improvement in the symptoms. It is, in fact, merely an indefinite prolongation of the condition in which a nerve is when it has " gone to sleep " as the result of slight pressure. In this case the weakness, tingling, and anæsthesia pass away in a few minutes after the pressure is released.

When the neuritis of the median is at all severe, there will be marked trophic changes in the skin and joints. The skin becomes thin and glossy, especially on the fingers, and sweating is often profuse. This sweating does not occur if the nerve is divided, until the regeneration has proceeded to the stage of return of protopathic sensibility.

Besides the glossy skin, the finger pads become wasted and pointed, and the nails striated and brittle. Periarticular adhesions form about the phalangeal joints, causing stiffness of the fingers and sometimes considerable distortion. Massage, passive movements of the joints, and persistent galvanism will be the best line of treatment, though great patience is required in a severe case, eighteen months or two years elapsing before there is much improvement.

Sometimes a severe form of neuritis of the median and ulnar, and of the radial also, results from the too tight application of a bandage for the treatment of a sprained wrist or of a fracture of one of the bones in the forearm; as a result, the muscles waste, with the reaction of degeneration appearing, and later, contracture of the flexors of the fingers. Ischæmic myositis may be combined with this condition. This late contracture, together with the periarticular adhesions of the interphalangeal joints, cripple the hand for many months, from one to two years often elapsing before a moderately severe case recovers entirely. A useful method of treating such cases is by electric arm baths—a porcelain or earthenware bath of the required shape, holding from 2½ to 3 gallons. The forearm is immersed in this, with sufficient water just to cover the skin completely, and the electrode wires are attached to two paddle or racquet shaped copper electrodes, the anode behind the elbow, the kathode at the fingers. Using the constant current, e current is slowly turned on until the galvanometer marks about 40 ma. This should be allowed to run for about ten minutes, and then for another ten minutes the current should be diminished and reversed once a second. Owing to the fact that the current has an alternative path through the water of the bath, or through the water and the tissues of the arm, only a proportion of it passes through the limb roughly about one-third, but varying with the amount of water, the shape of the bath, and the extent to which the water covers the limb. The sinusoidal current from the alternating electric light mains is of little use in the treatment of these cases of neuritis, in my opinion, when the muscular testing has shown that the muscles do not react to faradism.

The above method of using the constant current in an arm bath is very convenient if the constant current is available on the electric lighting mains, because the cost of the current used is then negligible; but if the only available source of the current is a galvanic battery of wet or dry cells, it will be advisable not to employ this method, because the wastage of current will be a heavy drain on the resources of the battery, since two-thirds or more of the current that is being used in the treatment of the limb is being wasted in the water. Unless, therefore, current is available from the mains or from a battery of accumulators, both electrodes should not be placed in the same arm bath, but one of the wires may be attached to a large flexible plate electrode, and fastened around the upper arm, while the hand rests on the kathode (*see* p. 228). With this arrangement there will be no wastage of current, all that is marked on the galvanometer passing through the tissues of the limb, and therefore not more than 7-10 ma. must be employed. Care must, however, be taken that the anode is applied to the upper arm, and that blistering of the skin is not allowed to take place, owing to the use of too strong a current, or drying up of the electrode covering, or unequal pressure of the metal upon the skin.

ISCHÆMIC MYOSITIS

Another very serious result of the too tight application of a bandage upon the soft tissues of the limb is **ischæmic myositis** (p. 131). This is produced by the tightness of the bandage squeezing the blood and lymph out of the limb, and thus damaging the nutrition of the muscles, so that a condition resembling a premature rigor mortis is set up. The condition was described by Volkmann, and is sometimes known as Volkmann's contracture, and most frequently affects the biceps or flexor muscles of the forearm. In some of these cases the nerves and nerve endings do not appear to be damaged, and then there is no alteration of the electrical reactions, although the muscles are contracted and paralysed. The contracture is primary, occurring within a few days of the application of the tight bandage, and is thus easily to be distinguished from the late contracture resulting from a nerve lesion and its consequent muscular wasting. Moreover, in ischæmic myositis there will be no other sign of nerve involvement, such as anæsthesia, glossy skin, wasted finger tips. etc. In the majority of cases, however, of ischæmic myositis that I have met with there have been, in addition to the primary muscular contracture, signs of nerve involvement by the pressure of the bandage, as shown by anæsthesia and reaction of degeneration of the muscles.

The contracture in ischæmic myositis is very obstinate and resistant to treatment, prolonged massage and passive movements over a period of many months being the only remedy short of lengthening the tendons. This is sometimes done by splitting the tendons, and then lengthening them, but it involves a long and tedious operation. A quicker way out of the difficulty practised by some surgeons has been to take a piece out of the bones of the forearm, thus shortening the whole limb, so that the flexor tendons will then allow the fingers to be straightened out.

NERVE INJURIES OF THE LOWER EXTREMITY

The nerves of the lower extremity are much less frequently injured than those of the upper, due to the facts that the lumbo-sacral plexus is shielded from injury in the pelvis, and also to the greater size and strength of the thigh and leg affording greater protection to the nerves. The lumbar or sacral plexus is sometimes involved in syphilitic gummata, and pain in the limb with rapid muscular wasting should suggest the trial of anti-syphilitic remedies. It is true that the sciatic nerve is much more liable to neuritis from cold, gout, or rheumatism than is the brachial plexus, and it is also sometimes directly injured by gunshot wounds or a stab. Similarly the anterior crural nerve may be occasionally injured by a wound in the groin or front of the thigh, causing wasting of the quadriceps extensor and weakness of extension of the knee, with loss of knee-jerk.

In the leg, the **peroneal nerve,** or external popliteal, as it is also called, is sometimes injured by pressure under an anæsthetic, or by a blow where it is liable to injury as it winds round the neck of the fibula. This injury may result from a slip between a railway carriage and the platform, jamming the leg below the knee. Another cause of pressure on the nerve is seen in the trade of carpenters and slaters, from lying on one side across the joists while at work on a floor or roof. As a result of this crushing of the nerve, there will be paralysis of the peronei, and of extension of the toes and dorsiflexion of the ankle, with anæsthesia of the dorsum of the leg, ankle, and foot. There will be foot-drop, necessitating the foot and knee being raised high in walking; a steppage gait, the foot flapping and being turned inwards. A gouty or rheumatic neuritis of this nerve, or portions of it, sometimes occurs, causing pain along the front of the leg, and weakness and wasting of the tibialis anticus, the extensor longus digitorum, the extensor longus hallucis, or of the peronei. Either one or more groups of these muscles may thus suffer in one leg.

Treatment of peroneal neuritis.—In the stage of complete muscular paralysis, if the neuritis is a severe one, there will be fully-developed reaction of degeneration, and therefore the constant current is the only form of current which will evoke muscular contractions. A good method of giving the electrical treatment will be to fasten a flat plate electrode by bending it around the upper part of the leg, and tie it on with a bandage to prevent it from slipping. The electrode must, of course, be thoroughly wetted, and the foot then placed in water in a shallow foot bath. The other electrode should then be placed in the water with the foot, and the current turned on until a strength of 8 ma. is registered by the galvanometer. The current should then be reversed in direction about once a second, either by working the current reverser on the battery by hand, or else by means of the metronome automatic reverser. As the faradic reactions return, with commencing recovery of the nerve, it is a good plan to apply the combined faradism and galvanism in this way, by turning the switch of the combined battery halfway between F and G, or by connecting the positive pole of the galvanic battery to the negative of the secondary faradic coil, and connecting the electrodes to the remaining two binding-screws, if a combined battery is not available.

Another way of applying the current, which is also useful, is to fasten the indifferent electrode to the thigh just above the knee, and use a roller electrode for the treatment electrode, connecting it to the negative pole or kathode of the battery. Using the kathode thus for the treatment by roller electrode, a certain amount of massage is combined with the application of the electricity. Massage should also be given separately, best daily, and passive movements and movements of the muscles executed against graduated resistance will form an important part of the treatment, as soon as there is a slight return of voluntary power, or from the commencement in those slighter cases in which the whole nerve has not suffered completely. This combination of passive movements and the execution of movements against graduated resistance form the principle of what is usually called "Swedish massage," a method which is a most useful adjunct in the cure of the slighter cases of muscular paralyses due to neuritis, and in the later stages of recovery of those cases in which the paralysis is complete at first.

TUBERCULAR NEURITIS

This is comparatively rare. I have once seen a severe case of multiple neuritis in which the only cause apparent was a widespread miliary tuberculosis, ending fatally. Alcoholic neuritis is common enough in conjunction with pulmonary tuberculosis, but in those cases the alcohol is the prime factor, and the pulmonary tuberculosis is largely dependent upon the diminution of resistance to tubercle invasion, owing to the condition of chronic alcoholism. The multiple neuritis in these cases is of the type familiar in alcoholic neuritis, but it is, of course, possible that the development of tubercle in an alcoholic subject may precipitate the occurrence of multiple neuritis, by the simultaneous action of two possible causes of neuritis, just as in the case of alcohol and arsenic. Severe brachial neuritis on one side I have also seen occur during the development of very rapid and fatal pulmonary tuberculosis on that side. Tubercular neuritis may also affect the feet, as I have seen several times, causing severe, almost continuous pain for weeks in both feet, with wasting of the skin and muscles of the feet. This latter condition, with hyperæsthesia of the skin of the feet, and irregular pyrexia, and with perhaps signs of tubercle in the lungs, kidney, or elsewhere, is, I think, characteristic of tubercular neuritis.

Electrical treatment may be of a certain amount of use in allaying the pain which is a prominent feature in tubercular neuritis. The constant current should be used, with both the feet placed in warm water in a foot bath, together with the anode; while for the kathode a large flat electrode is used and applied to the lower part of the back. The principle of cataphoresis may also be taken advantage of, and the foot painted first with an anodyne liniment of belladonna and aconite; or, instead of using a foot bath, the foot may be wrapped in lint soaked in this anodyne liniment, and a flat plate electrode attached to the anode bent round the foot outside the moist lint. By this means the belladonna and aconite will be carried through the skin by the cataphoretic action of the constant current from the anode.

ASCENDING OR MIGRATORY NEURITIS

is a rare affection, most commonly septic in origin. Thus, it may affect by extension the brachial plexus, after a peripheral twig has been involved in a septic process from a wound, whitlow, etc. Starting with pain along the peripheral branch of the nerve involved, local muscular wasting may follow, and later, wasting of other muscles proximal to the part first affected, by the extension upwards along the nerve of the septic process. The process is usually very slow, taking many months, or even years. I have thus seen a spreading neuritis of the brachial plexus, causing severe pains down the arm and hand, with glossy skin of all the fingers and fixation of the interphalangeal joints, follow an operation exposing the three upper nerves of the brachial plexus in the neck. There was a slight septic infection of the wound, which was followed later by pain in the hand, etc. This is a most difficult condition to treat, anodyne liniments, menthol and chloral paint, and cataphoretic constant current being the most successful. In this case the anode must be applied to the neck above the clavicle, and the whole of the forearm should be immersed in an arm bath with the kathode. Great care must be taken that no electrolysis of the skin is permitted, and the skin under the anode above the clavicle must be carefully watched for any signs of blistering, the anode being lifted up gently every few minutes for inspection of the skin. The strength of current should not be more than 10 ma., and the anode should rest on a bed of cotton wool soaked in the anodyne liniment. In very severe cases, in which the pain of a brachial neuritis is constant and excessive, the question of operation for division of the posterior spinal roots may have to be considered.

CHAPTER VI

GALVANISM (*continued*)

CRANIAL NERVES

THE cranial nerves are frequently involved by neuritis, due either to pressure from an intracranial growth or hydrocephalus, or to involvement in an acute or chronic meningitis of tubercular, syphilitic, or carcinomatous origin.

The **optic** or **second cranial nerve.**—This nerve may be damaged by optic neuritis and a subsequent secondary optic atrophy, or it may degenerate slowly from primary optic atrophy. The former is a common symptom in cerebral tumour, and in other causes of increased intracranial pressure; while primary or simple optic atrophy is met with in tabes dorsalis, disseminated sclerosis, syphilis, Leber's family type of optic atrophy, and as a result of pressure on or lesions of the optic tracts, chiasma, or optic nerve behind the globe.

Galvanism is sometimes recommended for the treatment of optic atrophy, usually the primary form, in tabes or in late syphilis.

In the application of galvanism for the treatment of optic atrophy two padded disc electrodes should be used, one two inches in diameter, attached to the anode and held against the temple, while the other should be smaller, one inch in diameter, attached to the kathode, and gently stroked over the upper lid or softly pressed under the eyebrow. A strength of 2 to 3 ma. should be used, and if the eyelid is too tender to permit of the kathode being stroked over it, the electrode should be pressed gently under the eyebrow and the current reversed at intervals of about once per second. Stimulation by this means of the normal retina produces a sensation of flashes of light in the eye, of a bluish tint, more brilliant with the kathode, and of a more violet hue with the anode. It is best to have the two electrodes close together, one on the eye and one on the temple, rather than that the indifferent electrode should be placed on the back or on the back of the neck. This is because with the latter method the current would be diffused through the skull and its contents, while by keeping the two electrodes as close as possible the current is confined to the eye and its immediate neighbourhood, and the brain is thus less affected. A very convenient method is to use rapidly reversed galvanism by a Leduc motor. If strong currents are passed through the brain by placing one electrode on each side of the head, and reversing currents of more than 5 ma., intense giddiness and nausea may be produced. If the electrodes are held over the region of the angular gyrus on each side, coloured yellow vision may be produced.

I have never seen so-called galvanism of the optic nerve do the slightest good in tabetic optic atrophy, but it may be of benefit in tobacco amblyopia or in similar conditions of toxic amblyopia, or in retrobulbar neuritis. Galvanic shocks passed through the eyes are sometimes of use in curing **hysterical blindness,** and in these cases, while the current is being applied, the patient should be made to keep the eyes shut, and encouraged at the same time with strong reassurances as to the improvement in vision that will result as soon as the eyes are opened after the electrical treatment is finished.

Hysterical blindness consists of diminished acuity of vision of varying degree, usually with peripheral constriction of the fields. In rare cases this peripheral constriction is so great that only about 5° around the fixation point remain, the so-called pin-point fields, which are usually bilateral. More commonly, there is greater peripheral constriction in one eye than in the other, with, at the same time, greater diminution of acuity of vision, especially when there are hysterical hemianæsthesia and hemiplegia, deafness, loss of taste and smell on the same side. Sometimes the peripheral constriction is much more marked on one side than on the other, resembling somewhat the half-fields in hemianopia due to a lesion of the visual centre or of the optic radiations or optic tract. In the hysterical case, however, there is marked peripheral constriction of the remaining half-fields in addition to the blindness on one side, whereas in hemianopia of organic origin there is little or no peripheral constriction of the remaining half-fields.

Sometimes hysterical amblyopia may be so intense as to amount to actual apparent loss of perception of light in one or both eyes. The pupils will, however, react normally to light, unless at the same time belladonna or some similar drug paralysing the sphincter of the iris has been placed on the conjunctiva with intent to deceive. Such combination of hysterical blindness and fraudulent dilatation of the pupil I have known kept up for four years, and to have deceived at least two eminent practitioners before the fraud was discovered. A combination of fraud with hysterical symptoms is, indeed, quite common, and is probably to be explained by the peculiar mental attitude of the hysterics, who are in a condition of self-hypnotism and usually craving for sympathy, of which they get less than they think they deserve. Another reason for this combination of hysteria with deceit is a congenital moral obliquity, often approaching the border line of actual insanity, from which they suffer. This is, I think, well shown by the numerous cases of clairvoyants and mediums who have been detected in fraudulent practices to assist their performances.

Ocular paralyses.—Paralyses of the third, fourth or sixth cranial nerves, causing different varieties of paralysis of the ocular muscles, have been in some cases benefited by electrical treatment. Before attempting to apply the current, however, it will be necessary to determine accurately which of the ocular muscles are at fault.

Third nerve paralysis.—This may be due to a lesion of the third nucleus in the floor of the aqueduct, or to a tumour, meningitis, fracture, or other mischief involving the third nerve in its course in the wall of the cavernous sinus, or its passage through the sphenoidal fissure and the back of the orbit on its way to the muscles of the eyeball. The muscles supplied by the third or oculo-motor nerve are the superior, internal, and inferior recti, the inferior oblique, the levator palpebræ, the ciliary muscle, and the sphincter of the iris. Paralysis of this nerve will, therefore, be followed by complete ptosis, or dropping of the upper eyelid, and external strabismus, the eye being turned outwards and slightly downwards, with almost complete immobility. In addition, the pupil will be medium dilated and fixed, and there will be complete paralysis of accommodation.

In slighter cases the ptosis may be incomplete, and there will be partial ability to move the eye towards the middle line; or one or more branches of the third nerve may be picked out by a lesion of the nucleus or of a division of the nerve in the orbit.

The commonest cause of third nerve paralysis is syphilis, due either to a gumma or gummatous meningitis, or to tabes, in which disease and in general paralysis of the insane partial or complete third nerve paralysis is very common. The Argyll-Robertson pupil, or loss of pupil reaction to light, with preservation of reaction to accommodation and convergence, is also a post-syphilitic phenomenon in practically every case, and due to nerve-cell or fibre degeneration in the neighbourhood of the third nerve nucleus.

The **electrical treatment** of the ocular muscles is never very satisfactory, inasmuch as they are out of sight and are so small that no obvious results of stimulation are apparent at the time. Again, the conjunctiva, through which the current has to be applied, is so sensitive that only weak currents can be employed. It is best to instil a couple of drops of 10 per cent. cocaine solution into the eye before applying the current. Galvanism should be used, and a good plan is for the operator to hold one electrode, moistened, in his own hand, and to apply the current to the eye with the tip of the forefinger of the other hand. The tip of the finger should be applied as much to the side of the eye as possible over the muscle which is to be treated, though no contraction of the muscle will be seen. The other electrode should be a round disc electrode applied to the temple, just as in treating optic atrophy. The duration of the application should be about ten minutes, the direction of the current being frequently reversed.

In *myasthenia gravis* ocular paralyses are commonly present, though the degree of weakness varies from time to time. The facial muscles almost invariably suffer also, especially the frontalis, orbicularis palpebrarum, and zygomatici. The lower jaw, too, frequently drops towards the end of a meal, owing to early fatigue of the masticatory muscles. In this disease treatment of the affected muscles may sometimes be of benefit, though not much is to be hoped for in the majority of cases. The etiology of the disease is uncertain, no lesion being present in nerve cell, nerve fibre, or muscle end-plate, though many of the muscles show infiltration with round lymphocytes.

The **fifth cranial** or **trigeminal nerve** is a mixed motor and sensory nerve, carrying the sensory fibres for the third, fourth, fifth, and sixth and most of the seventh cranial nerves, four of which are exclusively motor in function. Paralysis of the fifth nerve will cause loss of power in the masticatory muscles on one side, the following muscles being paralysed and wasting: masseter, temporal, internal and external pterygoid, mylohyoid, anterior belly of the digastric, and the tensor tympani. No contraction will be felt in the masseter or temporal on that side when clenching the teeth, and in opening the mouth the lower jaw will fall away towards the paralysed side, owing to unopposed action of the external pterygoid of the sound side. Reaction of degeneration may be obtained in the masseter, though it may be difficult to demonstrate if the overlying facial muscles are normal. The sensory paralysis of the fifth nerve will cause anæsthesia of the half of the head in front of a line joining the two auditory meati over the vertex. This includes the forehead, eye, nose, cheek, chin, inside of ·ose, cornea, and conjunctiva, inside of mouth, tongue, and hard palate, the anæsthesia ceasing at the junction of the hard and soft palates, and the anterior pillar of the fauces. Usually the sense both of smell and of taste on th. same side will be impaired or lost after a short time, owing to less of the trophic influence of the nerve on the sensory mucous membrane. Corneal ulcer or conjunctivitis may develop owing to the anæsthesia of the cornea, and the consequent accumulation of gritty particles, while the corneal reflex will be lost.

The treatment of fifth nerve paralysis will depend on the cause. If it is due to an intracranial gumma, iodide of potassium must be given in increasing doses ; but if due to the pressure of an intracranial growth other than syphilitic, no medicinal treatment will be of any service. Treatment of the wasted masseter and temporal may be attempted with galvanism, using the kathode with 5 to 6 ma.

The chief disease of the fifth nerve in which electricity is likely to be of service is **trigeminal neuralgia.** In this most serious neuralgia the pain may be sometimes allayed by passing a constant current of 4 or 5 ma. through the face, placing a round disc electrode over one of the tender spots, such as on the cheek-bone below the eye, or at the side of the chin. The cataphoretic current may be made use of, and a saturated solution of cocaine and guaiacol should be applied with the anode, the kathode being fastened to a plate electrode over the back of the neck. By this means the skin can be made anæsthetic under the anode owing to the cocaine being carried into the tissues by means of the anodal diffusion. Neuralgia of the face and head may also be relieved in suitable cases by means of the static spray or negative breeze from the Wimshurst static machine (*see* p. 360).

The *seventh or facial* nerve has already been dealt with (p. 153).

The eighth or auditory nerve.—Electricity is sometimes used in the treatment of deafness, galvanism being the best form of current to employ if tinnitus is a prominent symptom. The external auditory meatus should be filled with water, the head being held on one side. The anode is used for treatment, being attached to a laryngeal electrode—a stiff wire insulated nearly to its end, which is screwed into a small knob. This knob is placed in the meatus in contact with the water, while the kathode is attached to a round disc electrode and held against the mastoid on the same side. A constant current of 5 ma. should be turned on gradually, and should be allowed to run for ten minutes. A good plan is to combine this treatment with slow pulsating faradism, the interrupting hammer being so arranged as to vibrate slowly, about twice per second. Care should be taken not to interrupt the constant current, and not to use a strong galvanic current, as a disagreeable shock and vertigo might be thus produced. Considerable improvement in hearing sometimes results from this method of treating chronic non-suppurative middle-ear catarrh, with commencing labyrinthine symptoms.

VAGUS AND SPINAL ACCESSORY NERVES

Under this head are included affections of the soft palate, vocal cords, sterno-mastoid and trapezii muscles.

Paralysis of the **soft palate** may occur on both sides in bulbar palsy due to chronic degeneration of the nucleus ambiguus, or motor nucleus of the glosso-pharyngeal and vago-accessory nerves. It may also occur bilaterally in bulbar palsy due to other causes, as syringomyelia and tumours of the medulla; but the commonest cause will be post-diphtheritic neuritis. On one side only the soft palate may be sometimes paralysed in hemiplegia, or by a unilateral lesion of the medulla, in syringomyelia, or by meningitis or tumour implicating the vago-accessory nerve on one side of the medulla. Lead poisoning and syphilis may also cause palatal palsy. On phonation the raphé of the soft palate will be drawn over to the sound side, while at rest the arch of the palate will hang lower on the paralysed side. Stimulation of the velum by faradism will not provoke a contraction on the paralysed side, while by galvanism a sluggish contraction may be evoked; that is to say, there is RD. A laryngeal electrode should be used, insulated except at the tip, which is rested against the soft palate, and interrupted or reversed galvanic shocks should be given, using a current of 3 ma. The indifferent electrode should be a flat plate applied to the spine in the cervical region. This treatment may accelerate the recovery of the soft palate in post-diphtheritic paralysis, and possibly also in myasthenia. In the rare cases of chronic bulbar palsy following diphtheria, I have seen this treatment followed by considerable improvement and recovery in two cases, though a third was not permanently benefited.

Laryngeal paralysis.—Loss of voice, or **aphonia,** is a fairly common condition due to hysterical weakness of adduction of the vocal cords. There is whispering voice, with inability to phonate aloud; and when the larynx is examined with the laryngoscope the vocal cords are seen to be of the normal brilliant white colour, but widely separated, and only making very slight movements of adduction on the attempt to phonate. Proof that the adductor weakness is functional and not organic in origin is afforded by the demonstration of an inconsistency in the power of the adductors, because, although they will not adduct the cords when attempting to phonate, yet in the reflex act of coughing they act perfectly and close the glottis previous to the explosive expiration producing the cough.

This condition of hysterical aphonia is most commonly met with in young women, and is apt to recur at various times, like other hysterical symptoms. If of recent onset, it can often be cured at once by electrical treatment, though the **faradic current** will be much better for this purpose than the galvanic. The laryngeal electrode should be used—a stiff wire ending in a small knob, and insulated from its binding-screw attachment up to the base of the knob. This electrode can be bent into any shape, and when used for intralaryngeal application it should be bent at a right angle at a distance of two inches from its end. The faradism used should be moderately strong, and should be previously tested with a suitable electrode upon the thenar eminence, being sufficiently powerful to produce brisk contractions of the thenar muscles. The Wagner hammer of the faradic battery should be set to vibrate as rapidly and as loudly as possible, and then, before starting the machine, the electrode should be rapidly introduced over the back of the tongue into the larynx, so that the knob shall lie somewhere between the vocal cords. The battery should then be started, and the current application continued for periods of three or four seconds, the current being now started and stopped by a finger controlling the interrupting hammer. This is better than using a switch attached to the electrode itself, such as is supplied on the handle of a "testing electrode." It is a much more certain way of stopping the current, and has the advantage of stopping the noise of the battery at the same time as the current is arrested.

In a great many cases of functional or hysterical aphonia a rapid cure will be effected by this faradic treatment, the patient being encouraged to speak after the current has been turned on and off three or four times.

Another way of treating the larynx is to use two small disc electrodes, and to hold one on each side of the neck against the larynx. With this method, either faradism or interrupted galvanic shocks can be used for stimulating the laryngeal muscles, and it is sometimes used in abductor paralysis of the cords, due to neuritis or injury of the recurrent laryngeal nerve.

Abductor palsy may be unilateral or bilateral. When unilateral, it may be due to a lesion of the nucleus or of the vagus between the medulla and the jugular foramen, from meningitis or a growth, or to a lesion of the vagus or recurrent laryngeal in the neck; the recurrent laryngeal on the left side is given off from the vagus in the thorax, and winds round the aorta, and therefore may be damaged by an aneurysm or mediastinal tumour. When the vago-accessory is damaged at the base of the brain, or by a nuclear lesion of the nucleus ambiguus, the soft palate, as well as the vocal cord, is paralysed on the same side as the lesion, while in recurrent laryngeal paralysis the vocal cord will be paralysed alone.

Weakness of the vocal cords is a common symptom in *myasthenia gravis*. In this disease the muscles soon become fatigued, and whispering voice after a spell of talking, or at the end of the day, is due to the fatigue of the laryngeal muscles. Strong faradic or galvanic shocks are not indicated in the treatment of myasthenia, on account of the exhaustion of the muscles that can be produced by this means, at all events by faradism, the so-called myasthenic reaction.

Hysterical mutism.—This is a complete loss of speech of functional origin, and generally unaccompanied by any paralytic symptoms. It is usually seen in young women of an hysterical type, often as the result of some mental shock or prolonged anxiety. It consists of complete loss of all articulate speech, with preservation of the power of hearing and understanding everything spoken or written, and of the power of writing. It is to be distinguished from hysterical aphonia, and from aphasia of organic origin. From the former it is, of course, easily and at once distinguished by the fact that in hysterical mutism the patient is unable to speak a single word, while from aphasia of organic origin the distinction may be much more difficult. In the mutism cases there will very likely be some history of nervous shock or excitement, but there will be no sign of right hemiplegia, such as is generally present in aphasia of organic origin. In hysterical mutism there will be perfect ability to understand all that is said or written; but the aphasic is almost invariably unable to write, and there may be also inability to understand spoken words or written characters; that is to say, the aphasic will almost certainly also show signs of agraphia, and perhaps also of alexia or amnesia.

Hysterical mutism is especially likely to yield to electrical treatment, but either faradism by the wire brush, or sparks from the static machine, should be used rather than galvanism.

Laryngeal epilepsy, laryngeal vertigo, or ictus laryngeus, is a form of reflex epilepsy which is especially likely to occur in the subjects of bronchitis, or in those who have developed a stenosis of the glottis from ulceration of the cords, as may happen after typhoid fever. The attacks are typical epileptic attacks, but preceded for a few seconds by a definite laryngeal aura of a tickling sensation in the larynx accompanied by a slight feeling of suffocation and vertigo, and they are quite distinct from the laryngeal crises of tabes. I have seen the frequency of the attacks much diminished by regular intralaryngeal applications of faradism on alternate days, but at the same time, in suitable cases, a course of bromide should be given.

The **sterno-mastoid** and **trapezius muscles** are supplied by the spinal portion of the accessory nerve, and in cases of damage to the vago-accessory at the jugular foramen these two muscles will be paralysed and degenerate in addition to the soft palate and vocal cord muscles. These nerve fibres originate from the spinal cord as low down as the sixth cervical segment, and run upwards to join the vagus within the skull. The sterno-mastoid and trapezius muscles may, therefore, waste as the result of cervical lesions of the cord, due to myelitis or chronic pachymeningitis, in which case there will be additional symptoms of spastic paralysis involving the lower limbs, trunk, intercostals, and forearms. When the spinal accessory is injured in the neck, the sterno-mastoid and trapezius will be paralysed without the vocal cord or palate. This nerve may be injured by operations near the angle of the jaw, as for ligature of the lingual artery, or in the operation of nerve-anastomosis for facial paralysis, in which the peripheral end of the divided facial nerve is sometimes united to the spinal accessory, sometimes to the hypoglossal nerve. The nerve pierces the sterno-mastoid muscle at a point higher than where it leaves it at its middle posterior border. Between its point of exit from the sterno-mastoid and its entry into the trapezius, the nerve not uncommonly is divided accidentally during an operation for excision of tubercular glands in the neck, in which case the trapezius alone will waste. This muscle, although it is also supplied by the third and fourth cervical nerves, generally wastes with virtual completeness—upper, middle, and lower fibres—as the result of such a division of the spinal accessory nerve. The nerve is also sometimes divided intentionally for the treatment of spasmodic torticollis, on the central side of its entry into the sterno-mastoid muscle. As a result, of course the trapezius, as well as the sterno-mastoid, will waste.

The appearance of the back and shoulder in atrophy of the trapezius is characteristic. The shoulder appears more square and hollowed out, especially from behind, owing to the loss of the thick muscular portion attached to the acromion and occiput. The clavicle is now visible from behind, and the shoulder-blade hangs rather higher than its fellow, due to the lack of the downward pull of the lower fibres and the unopposed action of the levator anguli scapulæ and rhomboids. At the same time, owing to the loss of the middle fibres the vertebral border of the scapula hangs further out from the middle line of the back, and the scapula appears slightly winged, the lower border being tilted inwards by the pull of the rhomboids.

Paralysis and permanent atrophy of the middle and lower portions only of the muscle on one side may result from injury of the third and fourth cervical nerve branches; this occurred in a man in consequence of a severe fall from a height on to his left shoulder, causing an enormous hæmatoma at the back of the neck.

During the process of wasting after acute neuritis or injury, the electrical reactions will be those of degenerating muscle, RD of varying degrees being found. Treatment should be given by daily applications of galvanism by the labile method, the indifferent electrode being placed low down on the back, using a large round disc electrode for the kathode or treatment electrode, and a current of 7–8 ma.

In cases of division of the spinal accessory nerve, electrical treatment will be of no avail unless the divided nerve has been sutured. This is usually not possible after division of the nerve during an operation for the excision of tubercular glands in the neck, as the nerve is probably buried in a mass of glands, and a large piece of it is probably excised along with the glands. If an accidental stab in the neck has divided the nerve, then suture followed by persistent treatment by galvanism may result in recovery of the paralysed muscle after from six to twelve months.

Double trapezius palsy with atrophy is not uncommon in the muscular dystrophies, in which both upper and lower portions of the muscle may completely disappear on both sides; but when this muscle becomes affected in progressive spinal muscular atrophy the upper portion usually remains intact until late in the course of the disease. I have once seen complete double atrophy of the trapezius follow operation for clearing away tubercular glands from both sides of the neck.

Bilateral atrophy of the trapezius does not cause falling forwards of the head unless the complexus and other deep cervical muscles attached to the occiput are also involved, as may occur in progressive muscular atrophy, or chronic meningitis.

Sprengel shoulder is a condition of congenital malformation of the shoulder due to atrophy or non-development of the middle and sometimes the lower fibres of the muscle, causing the angle of the scapula to become tilted and to hang further out from the medial line of the back. In some of these cases there is present a bony junction between the upper border of the scapula and the transverse process of the neighbouring vertebra.

The **hypoglossal nerve** supplying the tongue muscles may be injured by an operation about the floor of the mouth, or the tongue may waste on one side after the performance of a nerve-anastomosis operation for facial paralysis, in which the central end of the divided facial nerve has been sutured into a slit cut in the sheath of the hypoglossal nerve. I have seen a case of facial paralysis resulting from nerve anastomosis which had been done two years previously, in which the sterno-mastoid and trapezius, as well as one-half of the tongue, were wasted, though no improvement had taken place in the facial paralysis. The tongue also wastes, usually bilaterally, in chronic bulbar paralysis, due to an atrophy of the hypoglossal nucleus. This occurs as a late event in the course of amyotrophic lateral sclerosis, or progressive muscular atrophy, in syringomyelia, and tumours or vascular lesions of the medulla. The tongue appears small and wasted, and is much ridged, with fibrillary tremors; while the patient cannot protrude it beyond the teeth.

Stimulation of the tongue by faradism or galvanism will show diminished muscular contractions to both currents. One electrode may be held in the patient's hand, while the bare end of the other wire is used as the testing electrode. In injuries to the nerve, or in other cases of rapid wasting of the muscle, the reaction of degeneration will be found. While testing with galvanism, only a few cells should be used, sufficient to give a current of about 3 ma. The galvanic current stimulates the nerve endings of the sense of taste, so that an acrid metallic, coppery taste will be noticed by the patient. This is stronger to the kathode than to the anode. This taste will also be perceived when the face is being treated for facial paralysis by galvanism.

In myasthenia gravis benefit may sometimes follow persistent treatment of the tongue, palate, and pharyngeal muscles with galvanism, in those cases in which the bulbar symptoms of weakness are prominent. In this disease there is usually no recognisable wasting of the tongue, though there may be considerable weakness of the upper and lower facial muscles. In chronic bulbar paralysis, due to nuclear lesions, there is almost always paralysis and wasting of the orbicularis oris together with the atrophy of the tongue. In rare cases of chronic bulbar palsy there may be also great weakness of some of the upper facial muscles, the orbicularis palpebrarum and the frontalis. Daily increasing injections of strychnine, with persistent galvanism, may occasionally cause marked improvement, though in the common type of chronic bulbar palsy sequent to amyotrophic lateral sclerosis I have never seen galvanism to be of the slightest service.

Bulbar symptoms without muscular wasting may also occur from symmetrical lesions above the medulla, in the pons, crura cerebri, internal capsules, or of the motor cortex. This condition is then known as pseudo-bulbar palsy. Electrical treatment is of no benefit.

CHAPTER VII

GALVANISM (*continued*)

PERIPHERAL OR MULTIPLE NEURITIS

WITH the exception of lead neuritis, which is practically a motor neuritis and confined to the upper extremities alone, multiple neuritis is most commonly due to chronic poisoning with alcohol. It is a fairly common sequel to diphtheria, sometimes to diabetes, and occasionally to arsenical poisoning, rheumatism, septicæmia, and other fevers. In tropical countries multiple neuritis occurs after beri-beri and malaria (*see* p. 152). It is thus always due to some circulating toxin or infective process, and the nerve lesion consists of a primary parenchymatous degeneration of the axis cylinders. The condition is usually acute or subacute, but alcoholic neuritis may become almost chronic, as the drug is continually renewed after each period of forced abstinence and the subsequent improvement in the symptoms. Lead neuritis, in the large majority of cases, is purely motor, neither pain nor muscular tenderness, nor trophic symptoms in skin, nails, or joints appearing; painful cramps in the muscles, especially in the calves, are not uncommon. In most other forms of peripheral neuritis the inflammation of the nerves is of mixed type, motor as well as sensory, though often in post-diphtheritic and sometimes in arsenical and in diabetic neuritis the symptoms are almost entirely sensory; numbness and anæsthesia of the legs, with ataxic gait, are often prominent, with little or no evidence of muscular weakness or foot-drop, so that these cases have earned the title of "pseudo-tabes."

Treatment.—In the acute stage of multiple neuritis, when there is much pain and tenderness, it will not be advisable to employ galvanism in the treatment unless it is possible to apply it in the form of the *galvanic electric bath.* In the most acute cases the pain and hyperæsthesia may be so intense as to necessitate wrapping the limbs in cotton-wool. Until this excessive tenderness passes off, no galvanism, massage, or strychnine injections will be tolerated.

In the less severe cases both massage and galvanism may be employed daily from the commencement; the labile method of applying the current should be used, the indifferent electrode being fixed to one of the limbs to be treated, and the kathode being used for the active electrode, employing a large padded disc electrode, with a current of 6-8 ma.

Care is necessary in many cases of multiple neuritis to prevent contractures of the hamstrings and gastrocnemii, from the legs remaining constantly flexed and the feet dropped. Passive movements, regularly applied, will counteract this tendency.

OCCUPATION NEUROSES

Various forms of fatigue spasms are met with, the commonest of which is known as "writer's cramp," or "scrivener's palsy."

An occupation neurosis declares itself mainly by four symptoms—spasm, weakness, pain, and tremor—the symptoms being referred especially to the part of the limb or body which is concerned with the repeated movement of the particular occupation. Thus, in **writer's cramp** the spasm affects particularly the small muscles of the hand moving the thumb and index finger, so that the pen or pencil is held with increasing difficulty and is either dropped or forced through the paper by jerky movements. At the same time, the hand is tremulous in writing, and neuralgic pain is complained of in the wrist and forearm, especially the front of the wrist and near the elbow. These symptoms in true writer's cramp are only noticeable during the act of writing, the hand and limb being perfectly normal for other movements. The disease is more likely to declare itself in a neurotic subject, with a family heredity for nervous ailments, as hysteria, epilepsy, insanity, etc. It is most common in those who have long hours of cramped writing to do, as in lawyers' clerks, rather than in those who cultivate a free style of writing, as reporters.

Exciting causes that are usually present are domestic worry about money affairs, illness, and other family troubles. It is often precipitated by some local disease affecting the arm, as muscular rheumatism due to a draught blowing from an open window on the right side, periostitis, or even the commencement of some organic spinal disease, as progressive muscular atrophy or syringomyelia. Or, again, the limb may be congenitally weak from some such cause as an infantile hemiplegia, or a slight attack of infantile paralysis in early childhood. In the treatment of writer's cramp it is, therefore, most necessary to inquire closely into the onset of the affection, and not only to examine the limb itself for any signs of local disease, but also to examine the nervous system thoroughly for any signs of grave organic disease. If any such local or general cause is found, the treatment must be in the main directed towards its cure, if possible, though at the same time rest for the limb, and perhaps electric baths, may be beneficial.

Treatment.—In the treatment of ordinary writer's cramp, absolute rest from writing is the essential part; while daily massage, galvanic arm baths, and if possible a change of air and scene, with a complete rest from business and other worries, will help in completing the cure. In the slighter cases adoption of a different pen and style of writing may arrest the progress of the disorder, or if the patient cannot leave his business it may be possible for him to perform most of his writing with his left hand. Electrical treatment alone of occupation neuroses is almost certainly doomed to failure; but in conjunction with the treatment outlined above various forms of electrical treatment may be of service.

Other occupation neuroses that are met with are telegraphist's cramp, piano and violin player's cramp, hammerman's cramp, and many besides. Cessation of the particular occupation is essential for them all.

There is another form of writer's cramp met with in excessively neurotic individuals, in which the muscular spasm and inability to write are most marked at the commencement of the day's work, or if anyone not perfectly familiar to them is near or watching them. This is not a fatigue spasm, but a habit spasm, or tic, and has been called **"pseudo-writer's-cramp."** I have seen this form associated with morbid ideas of self-consciousness and mental depression. Such cases require general moral tonic treatment, sometimes Weir-Mitchell treatment, change of scene, etc., rather than cessation from writing, massage, and galvanism to the arm.

SPASMODIC TORTICOLLIS

Or spasmodic wryneck, is a form of spasm closely allied to the occupation neuroses. Indeed, the spasm turning the head to one side may be originated by the constant repetition of one movement, as in drawing a thread through leather, swinging a riveting hammer, etc. The condition is to be distinguished from wryneck due to organic causes, such as rheumatic fibrositis of the neck muscles, cervical caries, enlarged glands. In these cases the neck is fixed in one position, and there is usually definite pain on movement, while in spasmodic torticollis the neck twist is usually a clonic spasm, and though perhaps distressing through its frequency and intensity, yet the spasm cannot be said to be actually painful. It is, in reality, a form of tic or habit spasm, and is a morbid reiteration of a movement originally voluntarily performed either on account of some peripheral irritation, or on account of defective vision of the eye on that side, or for some similar reason. Constant repetition of the movement, though entirely voluntary at first, gradually becomes more and more automatic at last in response to the idea of the movement, so that the spasm becomes riotous in degree as the voluntary inhibition is withdrawn. Thus the spasms are usually worse when the patient is alone or unobserved, and, indeed, the patient may have difficulty in demonstrating the morbid condition to the medical attendant.

Spasmodic torticollis is more frequently towards the left side, and consists of clonic spasms of the right sterno-mastoid, usually in association with the left upper trapezius, splenius, complexus, trachelo-mastoid, and oblique muscles. Occasionally the head is turned to the right, and then the left sterno-mastoid with the right posterior cervical muscle will be concerned in the faulty movement. There are generally to be found in the patient other signs of nervous instability, deficient will-power, hysteria, or other hereditary neurosis. Echolalia, or the impulsive repetition aloud of words or sentences just spoken either by the patient or by those around, is a curious psychical symptom sometimes combined with spasmodic torticollis.

In the **treatment,** any peripheral cause for the origination of the movement must be attended to, and regular exercises of the head and neck muscles should be performed daily before a mirror. Massage to the affected muscles, and also galvanism, may do some good. In certain obstinate cases where the spasm is only to one side, with little or no bilateral retrocollic spasm, division of the spinal accessory nerve on one side, with division of the posterior branches of the four upper cervical nerves on the other, may effect a cure. Relapse, on the other side, is unfortunately sometimes met with.

Galvanism should be applied as a constant current of 3 to 4 ma. to the back of the neck and to the sterno-mastoid affected by the spasm. The positive pole should be applied over the muscle near its insertion into the clavicle, using a round disc electrode 1½ inches across; while the negative electrode, as a flat plate, is applied to the nape of the neck. The current should be applied twice a day for fifteen minutes at a time, and at the same time gentle faradism of the opposite sterno-mastoid will usually increase the good effect.

RAYNAUD'S DISEASE

This is an extreme form of vaso-motor tropho-neurosis or defective circulation, the slighter forms of which are familiar to us as *dead fingers* and *chilblains*. In Raynaud's disease the extremities become cold and blue, and loss of tissue from small patches of gangrene are of not unfrequent occurrence along the edges of the ears and the pads of the fingers. Occasionally larger areas of necrosis are seen involving one or more finger or toe joints, and even the whole foot may be lost above the ankle in this way. The condition is usually more or less symmetrical. There is generally little or no pain, the sensations being more of numbness and deadness.

Raynaud's disease is to be distinguished from chronic ergotism, from erythromelalgia, and from local asphyxia and cyanosis due to endarteritis and peripheral neuritis. It is also possible that the cyanosis of the extremities due to congenital heart disease might be mistaken for it, or the blue pigmentation due to silver poisoning, or to the taking of methylene blue or acetanilide. In erythromelalgia the affected extremity swells up and becomes hot and livid, with swollen veins when the limb is hung down for a few minutes, though there may be little or nothing abnormal to be seen when the limb is kept raised. The pain, too, is then throbbing and severe. These two points serve to distinguish it from Raynaud's disease, and it is, moreover, usually associated with local endarteritis, neuritis, or some spinal disease as tabes or disseminated sclerosis.

Treatment.—Raynaud's disease is best treated with constant current galvanic baths given daily, the limbs being carefully kept covered and warm in the intervals, in the winter time loose gloves being constantly worn. The baths may be either full hydroelectric galvanic baths, as already described, or the applications may be local by means of arm baths or foot baths. If more than one limb requires treatment, the current may be passed through the body of the patient from one arm bath to the other, as in the four-cell Schnée bath. The current should not be interrupted, but should be given continuously for twenty minutes at a time daily. If only one arm requires treatment, the limb should be placed in an arm bath, with the forearm immersed up to the elbow, the fingers just reaching the electrode at one end of the bath. About 30 ma. of current should be used, of which it may be reckoned that 10 ma. are affecting the forearm and hand, the rest passing between the electrodes through the water only. If both arms require treatment, two arm baths should be used, and one electrode dipped into one, and the other electrode into the other bath. Then, with both forearms immersed in the water, the current should be turned on gradually until 10 ma. of current are registered, and allowed to run for twenty minutes. The arm which has the positive electrode in the bath one day should have the negative electrode the next day, and *vice versa.* No acid or salt should be put in the water, since this addition diminishes the resistance of the water, and thereby wastes more current.

An ordinary galvanic battery of eighteen cells will be quite easily capable of supplying the 10 ma. of current between the two arm baths if the cells are dry cells and new; but if only a single bath is used, with both the electrodes dipping into the water, it will be rather too great a strain on the small cells of an ordinary dry-cell battery, since they will be supplying current three times as fast as in the former case, and will therefore be worn out more quickly. As an alternative, one large plate electrode, well covered with flannel or other wetted material, may be wrapped round the upper arm above the level of the water in the bath, care being taken that the electrode does not touch the water at all. Then all the current that is used is confined to the tissues of the forearm if only the hand is dipped in the water with the other electrode. If, however, the forearm be completely plunged in the water, and the electrode applied to the upper arm, most of the current is dissipated into the water in the region of the elbow, and does not affect the lower part of the forearm and hand unless nearly as much current is used as when both the electrodes are dipped into the water, one at each end of the bath. Erythromelalgia may be also beneficially treated by this means.

CHILBLAINS (ERYTHEMA PERNIO)

Chilblains, one of the circulatory tropho-neuroses, is a condition somewhat allied to *dead fingers* and Raynaud's disease, but produces different effects. There is more swelling and itching and less cyanosis than in Raynaud's disease, followed by peeling of the skin, and in bad cases by cracking and bleeding of the skin. Though there is never gangrene as a result, the effect of the temporary malnutrition on the tissues is seen upon the nail as it slowly grows forwards, a deep furrow corresponding to the date of the chilblain, and showing its effect upon the nutrition of the matrix of the nail.

Treatment.—Various methods of treatment have been advocated for chilblains, one of the more recent being the administration of calcium salts by the mouth, on the supposition that the inflammatory swelling of the chilblain is an œdema dependent upon a diminished percentage of calcium salts in the blood. Some cases, undoubtedly, do benefit by this treatment, but certainly not all. Ichthyol by the mouth has also been strongly advocated. Probably the most effective and reliable treatment is by means of electricity. A very efficient method, if begun sufficiently early, before the chilblains have reached the cracked and bleeding stage, is to use combined faradism and galvanism in arm and foot baths. A large electrode attached to the positive pole should be wrapped round the arm over the elbow, and the hand placed spread out in water over another pad electrode attached to the kathode. The constant current should then be turned on until the galvanometer indicates 5 ma., and then the faradic coil current should be turned on gradually until the muscles are gently tetanised.

It is to be remembered in administering combined galvanism and faradism that the galvanic and faradic batteries must be coupled up in series (*see* p. 24); that is to say, that one pole of the faradic battery is to be connected with the pole of opposite sign of the galvanic battery; while the wires leading to the electrodes for treatment are attached to the two remaining binding-screws, one on the faradic battery and the other on the galvanic. In combined batteries provided with a de Watteville switch so that either current or both can be led out of the same pair of binding-screws, the battery should always be tested after being sent home, as the instrument makers, even when skilled electricians, do not always pay attention to this point. For instance, supposing the battery were originally fitted up with wet Leclanché cells, and the two cells for driving the faradic coil when exhausted have been replaced by dry cells; it will then be necessary to reverse the wires connecting the poles of the cells, as with dry cells the centre rod is carbon and the outside case is zinc, the reverse arrangement to that in some wet cells, while other wet cells have the zinc placed outside the carbon, as in the dry cells.

Faradism has a better effect on chilblains than has the direct current, and is more pleasant when given in a water bath. The effect of the soaking of the skin in water is not good, however, especially in cold weather, in those persons with bad circulations who are liable to chilblains, and it is therefore preferable to use a form of electric treatment in which moistening of the skin is not necessary. For this reason treatment by high frequency currents is preferable, using vacuum electrodes on the condenser couch, the vacuum electrodes being applied locally.

GRAVES'S DISEASE

Exophthalmic goitre, or Basedow's disease, as it is named on the Continent, is partly a neurosis, and partly due to faulty metabolism from excessive hypersecretion of the thyroid gland. The three most important symptoms are tachycardia, exophthalmos, and goitre. In addition, staring eyes, due to retraction of the upper eyelids, tremors, flushes and sweats, vomiting, diarrhœa, amenorrhœa, anæmia, pigmentation of the skin, insomnia, and other neurasthenic symptoms, and even mania, may supervene. Rarely, some of the symptoms may be unilateral, such as the goitre, the exophthalmos, the flushes, sweats, and pigmentation. The disease is very uncommon in men, being usually limited to young women, generally commencing between twenty and thirty, though it has been met with under twenty. There is often a history of mental shock or worry, such as nursing a sick relative ; and there is often a history of other neuroses in the same family, such as torticollis of the spasmodic type or "torticolis mental" of Brissaud, epilepsy, insanity, or migraine. The disease is often very resistant to treatment, and may continue for several years. Occasionally atrophy of the thyroid, with all the symptoms of myxœdema, has followed some years later.

It is not every case which presents all the typical symptoms as described above. The most easily recognised symptom is the staring eyes, due to the retraction of the upper eyelids, thus exposing the white sclera around the cornea. If this symptom, described by Stellwag, von Graefe, and others, is absent, as sometimes happens, the disease may easily be mistaken. The most constant symptom is the tachycardia, and certain cases present the symptom of persistent tachycardia without any ocular symptoms or goitre; and yet from the history of the onset, with the presence of other neurasthenic symptoms, flushes, sweats, etc., it is probable that these cases are to be classed in the same group as Graves's disease, and they are sometimes spoken of as "larval Graves's disease."

Treatment.—The treatment of Graves's disease may be grouped under four headings:

1. General management of the case.
2. Drug treatment.
3. Operation for removal of the thyroid gland.
4. Electrical treatment.

1. The *general management* of a case of Graves's disease is perhaps the most important part of the treatment. Rest, both physical and mental, is essential, avoidance of worry and excitement, and regular hours. Quiet country life, with gardening as an occupation, an hour's rest before lunch, and half a mile as the limit for a daily walk, should be the line of treatment, if possible, for a year or two. If the tachycardia, dyspnœa, and other symptoms are severe, complete rest in bed or on a long couch must be insisted on for several weeks.

2. The *drugs* that are usually employed in the treatment of this disease are digitalis, belladonna, and bromides. More recently, on the suggestion of Moebius, a drug named *antithyroidin* has been employed. This is prepared from the serum of sheep whose thyroid glands have been previously removed by operation. I cannot say I have seen any particular benefit follow in cases in which I have used it. It is, moreover, costly.

3. Removal of the whole or part of the thyroid gland has been many times performed in an attempt to remove what was thought at one time to be the sole morbid process of the disease, namely, hypersecretion of the thyroid gland. Disappointment followed because the treatment was

founded on a faulty pathological basis, since it is now clear that the nervous system is primarily at fault, and that the excessive functioning of the thyroid gland is only one part of the mechanism of the disease. If the whole gland is extirpated there is danger of the disease being complicated by the symptoms of myxœdema. One lobe of the gland is sometimes removed, and benefit has undoubtedly followed in certain cases; but it is more than doubtful whether the benefit is not due to the moral shock of the operation rather than to the actual removal of the glandular tissue.

Operation is sometimes urgently needed when there is evidence of compression of the trachea or œsophagus, causing dyspnœa or dysphagia. Division of the isthmus of the gland may then suffice to release the trachea from pressure.

4. **Electrical treatment.**—Various methods have been advocated by different observers; namely, treatment by the faradic current, by galvanism, by X-rays, by cataphoresis with iodine, and by electrolysis of the gland. Vigouroux's treatment by means of faradism was strongly recommended by Charcot. The method consists of four different modes of application of the current: (*a*) faradisation of the carotid, (*b*) faradisation of the eyeballs, (*c*) faradisation of the goitre, (*d*) faradisation of the præcordium.

(*a*) *Carotid faradisation.*—The positive pole of the induction coil is attached to a large electrode applied to the cervical spine, while the negative electrode, which is small and olive-shaped, is pressed on the carotid artery, ½ inch below the angle of the jaw, between the tip of the hyoid bone and the anterior border of the sterno-mastoid. The electrode is pressed on the vessel until the pulsations are felt, the head being turned slightly away. The vibrations of the interruptor should be rapid and the strength of the current just enough to throw the platysma into gentle contraction. This is continued for one and a half minutes, the process being then repeated on the other side. Diminution of the pulsations, pallor of the skin, and lowering of the surface temperature follow, effects which last longer after repeated applications.

(b) *Faradisation of the eyeballs.*—This is done by passing the same olive-shaped electrode around the eyes, using just sufficient strength of current to produce contractions of the orbicularis. This should be done for two minutes on each eye, the object being to cause contraction of the blood vessels at the back of the orbit, since it is largely the congestion of the fatty tissue at the back of the eyes which causes the exophthalmos.

(c) *Faradisation of the goitre.*—Leaving the electrode on the cervical spine in place, the olive-shaped electrode should be changed for a small flat one about 1½ inches square. This should be placed over the thyroid just above the episternal notch, or, if the goitre is large, it should be placed alternately on each lobe for two minutes.

This treatment is supposed to cause contraction of the arteries in the goitre, and to produce an effect on the internal secretion. That the arteries in the gland are much dilated in Graves's disease is evident from the loud bruit, systolic in time, that can be heard there by placing the stethoscope over the goitre. This bruit is never heard over the goitre in cases of cystic or parencyhmatous bronchocele.

(d) *Cardiac faradisation.*—A small flat electrode attached to the positive pole of the secondary faradic coil is placed on the third left intercostal space over the heart and a current just strong enough to produce weak fibrillary contractions of the pectoral is applied for between two and three minutes.

As a result of this treatment, after repeated sittings a rapid improvement, with diminution of the symptoms, is said to occur, the tremor and goitre being the first to subside, while the exophthalmos and tachycardia are more obstinate and persist much longer.

Another method of electrical treatment of Graves's disease is by *galvanisation*. For this purpose a well-padded flexible electrode of 5 inches by 4 inches is attached to the negative pole and carefully applied over the goitre, so that it is in perfect apposition with the skin and pressing evenly over the thyroid swelling. The positive electrode is applied to the back of the neck, and a steady current of 15 to 25 ma. passed through the goitre for twenty minutes. It is to be remembered that in Graves's disease the electrical resistance of the skin is less than in normal persons, and therefore a less number of cells will be required to send a given milliampèreage of current through the skin than in other cases. For this reason great care must be taken with the negative electrode over the goitre, as owing to the thinness of the skin there, it is very easy to produce an unpleasant burn through unequal pressure of the pad, or through using too strong a current. Not more than 10 ma. should be used for the first few minutes, and care must be taken that the pad is thoroughly wetted.

Of the two forms of electrical treatment, galvanisation is in the majority of cases to be preferred to faradisation for the treatment of Graves's disease; but if dyspnœa is present as a symptom, electrical treatment is contra-indicated and surgical aid is probably necessary.

LEUKÆMIA AND SPLENIC ANÆMIA

may also be treated with advantage in some cases by means of galvanisation to the enlarged spleen. The size of the electrode to be applied over the spleen must vary with the size of the organ; if the spleen reaches beyond the navel in an adult, a pad electrode of about 7 inches by 4 inches should be applied closely over it, and kept in position on the abdomen by means of a wide bandage. A similar electrode should be applied over the posterior pole of the spleen close to the spine. Care is to be taken in all such applications of galvanism that the pad is thoroughly wetted and is in close apposition to the skin over its whole area. The electrode over the spleen in front is to be attached to the negative pole, and a current of 15 to 20 ma. gradually turned on and allowed to run steadily for twenty minutes. Persistent daily treatment by this means has been recorded to produce considerable amelioration in the symptoms, and I have certainly seen great improvement in the size of the spleen, with marked reduction in the leucocytosis, occur in leukæmia after the galvanic treatment had replaced the treatment by arsenic, when arsenic alone had apparently done nothing but provoke severe bilateral herpes zoster on the trunk.

CHAPTER VIII

GALVANISM *(concluded)*

ELECTROLYSIS

THIS method of employment of the galvanic current is largely used for the destruction of nævi, hairy growths, and superfluous hairs and small moles upon the skin. It has also been employed in the treatment of aneurysm, uterine fibroids, scars, and strictures.

By electrolysis is meant the decomposition of a substance into its chemical elements, by the passage of an electric current through it. The current must be constant in direction, or chemical decomposition does not occur.

Electricity appears to be conducted in one of three ways: (*a*) by radiation, as in the aërial waves of wireless telegraphy; (*b*) by metallic conduction, in which the condition of the conductor is not altered by the passage of the current; (*c*) by electrolysis, in which the conducting substance is decomposed by the passage of the current.

Theory of ions.—According to Arrhenius, substanc in solution may be divided into two classes: those whose molecules undergo dissociation into their elements, and those whose molecules do not dissociate. Substances of the former class are the electrolytes; those of the latter are non-electrolytic. The only substances which are electrolytes are the acids, bases, and salts. Other substances, such as sugar, urea, albumen, and colloids do not dissociate at all when in solution, and therefore are not electrolytes.

Water that is chemically pure is a non-conductor, and therefore to render water a conductor of electricity it is necessary to add to it a small quantity of an acid, an alkali, or a salt.

When one of these substances is in solution, a certain number of its molecules are dissociated into the two atomic or molecular groups composing it—the hydrogen or metal with a positive charge of electricity, and the acid radicle with an equal negative charge. It is these groups that Arrhenius has named "ions." Thus, common salt is dissociated into the ions Na and Cl, sodium and chlorine, while sulphuric acid is dissociated into two ions of hydrogen and the ion SO_4. The more concentrated the solution the fewer are the molecules that are dissociated into their constituent ions, whilst in a very dilute solution all the molecules may be dissociated into ions. When a constant current is passed through such a solution between two electrodes, the electro-positive ions—that is to say, the bases such as sodium, potassium, hydrogen, and other metals—will become positively charged and will be therefore repelled from the positive pole and attracted towards the negative or kathode ; these ions are therefore called kations, or cations. The electro-negative ions—oxygen, chlorine, iodine, acid radicles, etc.—will become charged negatively and will be therefore repelled from the negative and attracted to the positive pole or anode. These ions are therefore called anions. The same element may be electro-positive in one combination and negative in another. Thus hydrogen is a kation in the solution containing hydrochloric acid (HCl), whilst in a solution of potash (KOH) the potassium acts as the kation and the hydroxyl group OH is the anion. The rapidity of the movement of the ions in the electrolyte —that is to say, the rapidity of the electrolytic action—varies directly with the voltage of the current, and also with the temperature, cold diminishing and heat augmenting the action. The lighter the molecular weight of the ion the more rapidly will it diffuse under the action of the current. Hydrogen has the lightest molecular weight of all known substances, and its ion moves the most rapidly.

The method of conduction of the galvanic current through the living body is by means of electrolytic action, and it is by the application of the theory of ions just described that the administration of drugs through the skin by means of the galvanic current is to be explained. This process has been already referred to under the title **cataphoresis.** Iodine and salicylic acid are the two drugs used by this method whose ions are usually electro-negative in their chemical relations, and therefore act as anions. On that account these drugs must be applied to the skin by means of the negative electrode, since being anions they will be attracted towards the positive pole, and will therefore penetrate the skin and enter the tissues when placed under the negative electrode or kathode. The iodine may be either painted on the skin, or a solution of iodide of potassium may be used to soak the padded kathode in. This treatment is used for rheumatic joints, and sometimes for enlarged glands, as in lymphadenoma. Salicylic acid is best used as a dilute solution of salicylate of soda applied to the kathode or negative electrode. The acid or salicyl radicle under the action of the galvanic current will then enter the tissues on its way to the positive pole. Cataphoresis, with salicylate of soda, is sometimes very useful in neuralgias, and especially in rheumatic neuritis, as sciatica or brachial neuritis (*see* p. 169).

The metals and the alkaloids will act as kations during the passage of a galvanic current, and in order to cause them to penetrate into the tissues by means of cataphoresis it will be necessary to apply their solutions to the anode or positive pole. Lithium is thus used in the treatment of gouty joints, and in so-called rheumatic gout. A solution of lithium chloride or carbonate is applied on lint under the positive pole to the joint requiring treatment, while at the same time iodine may be painted on the skin under the kathode, or the kathode may be soaked in solution of potassium iodide. If a large joint, as the knee joint, is affected, the anode and lithium may be applied on the electrode moulded closely around one side of the joint, while the kathode and iodine may be similarly applied on the other side of the joint. It was Edison who, in 1890, first suggested the use of lithium by this means for the solution in the tissues of the gouty deposits of biurate of soda; for urate of lithia is soluble in 116 times its weight of water, while urate of soda requires 19,000 times its weight of water for solution. Thus the foot or hand which is to be treated is placed in a bath of hot water containing 2 per cent. of lithium chloride, and attached to the positive pole; while the negative electrode, as a large plate, may be applied to the spine. A current of 40 or 50 ma. should be used for twenty or thirty minutes, great care being taken that it is not suddenly interrupted.

Zinc ions are recommended for the treatment of **rodent ulcer,** the mode of application being by means of bare zinc button-shaped electrodes of different sizes attached to the positive pole.

All the **alkaloids** are electro-positive, and so are attracted towards the negative pole. To force them through the skin by means of a galvanic current, therefore, they must, like the metals, be applied by means of the anode or positive pole. The alkaloids thus used are cocaine, morphine, aconite, and quinine. Each of these has been used for the treatment of neuralgias, such as tic-douloureux. If a solution of aconite or cocaine be applied to the positive pole and held against the skin while a galvanic current is passed for several minutes, it will be found that the skin is more or less anæsthetised, a prick not being felt as sharp.

That drugs are undoubtedly introduced into the tissues by means of cataphoresis has been abundantly demonstrated, Leduc's experiment with two rabbits showing conclusively that one of the animals can be killed by the introduction of strychnine or cyanide by this process. In his experiment two rabbits were fastened side by side on a board, and two pad electrodes were closely applied to each, one on each side of the back of the animal, so that there were four pads in a row—A, B, C, D. A was coupled to the positive pole of the battery and D to the negative, while B and C were joined together by a wire, the two animals being thus coupled up in series with a galvanic battery. The pads A and D were soaked in a solution of common salt, and the pads B and C in a solution of sulphate of strychnine. The current was then turned on gradually, about 50 ma. being used. After some time it was found that the C D rabbit developed increased deep reflexes, and later still died in convulsions. When another rabbit was substituted for this one the same thing happened, whilst if after replacing with a new rabbit the current was reversed in direction, the A B rabbit died, whilst the new one was unaffected. Now, in the original arrangement of the current the C D rabbit had the positive electrode C soaked in strychnine solution, whilst with the A B rabbit the strychnine was applied to the negative electrode B. It is clear, therefore, that the C D rabbit was poisoned by strychnine entering its body from the positive pole, while the A B rabbit was unaffected by the strychnine on the negative electrode, though when this electrode was made positive by reversing the current this rabbit died also. It follows that it is the action of the current that causes the drug to enter the tissues, and not the mere soaking of the skin with the drug in solution. If, instead of strychnine, cyanide of potassium solution is used for the electrodes B C on the two rabbits, B being the negative electrode or kathode, and C anode or positive, it will be found that the rabbit A B will be killed by cyanide poisoning, while the rabbit C D will escape harm. In this case the cyanogen radicle, being an anion will enter the tissues from the negative pole on its way to the positive pole.

A simple experiment will demonstrate easily and quickly this passage of the anions and kations, with the decomposition of the electrolyte. Moisten a piece of white blotting paper with a solution of potassium iodide, and lay it flat upon a board or marble slab. Take the two wire terminals of a strong galvanic battery and hold them on the blotting paper ½ inch apart, and turn on the current until 10 ma. are indicated. A strong brown stain will appear around the anode with the characteristic smell of iodine. With a stronger current, small flashes and sparks will appear at the negative pole owing to the rapid oxidation of the potassium ions attracted to the kathode. If salicylate of soda is used instead of iodide of potassium, most of the sparks and burning will appear at the positive pole owing to the further decomposition of the salicyl radicle.

As was said above, pure water is a bad conductor of the electric current, and requires the addition of a trace of an electrolyte, acid, base, or salt in order to render it a good conductor. It is then decomposed by the passage of a constant current, the hydrogen kations appearing at the negative electrode as small bubbles, while the oxygen either oxidises the anode if it is made of copper, steel, etc., or appears as bubbles if made of platinum. The mechanism of this process of decomposition of the water, or electrolysis, is no doubt due to the stress set up in the molecules of water by the difference in potential of the anode and kathode. The hydrogen and oxygen molecules, charged with equal and opposite quantities of electricity, have entered into combination to form water, neutralising their electric charges; but these are again split asunder under the compelling force of attraction of the anode and kathode for the separately charged constituents of the water molecule.

Just as no evidences of the transfer of these ions is seen in the body of the electrolyte, but only at the poles, so during the passage of an electric current through the body no evidence of dissociation of the tissues occurs except at the skin in contact with the electrodes. If metallic electrodes are in contact with the skin this will be rapidly softened and destroyed by the action of the caustic alkali generated at the kathode, and of the acid at the anode, and, therefore, so-called burns will occur if the bare metal is allowed to remain for long in contact with the skin. Therefore, in the ordinary applications of the galvanic current, pads soaked in a solution of some electrolyte, such as a weak saline, are fitted over the metal electrodes so that the products of electrolysis shall take place within the pads and not upon the skin. With strong currents, however, and prolonged applications, the acids and alkalies generated may soak through the pads and cause damage to the skin. It is, therefore, necessary when using strong currents for any length of time to examine the skin from time to time to avoid injuring it. The first sign of injury to the skin will be a smarting pain and the appearance of a small blister under the electrode, the skin underneath becoming dark coloured and ulcerated if the current is not stopped. Nasty sloughing wounds may be thus produced, which take a long time to heal and leave permanent scars.

This destructive action of the electrodes is made use of in the treatment of nævi, moles, uterine fibroids, etc.

NÆVI

These are usually situated about the head or neck ; they may be subcutaneous, forming small tumours under the skin, or they may involve the skin also. They may be large or small, from small red spots on the side of the nose or cheek to a large port-wine mark. They are often present at birth, and often grow rapidly if not operated upon early.

Nævi may be treated by electrolysis either by the bipolar or the unipolar method. With the former method two needles at least are inserted into the nævus, one attached to the positive and the other to the negative pole.

Bipolar method.—The two needles should be of platinum and should be inserted through the skin into the substance of the nævus at about $\frac{1}{2}$ inch apart, should the size of the nævus permit this. The needles must not be allowed to touch one another. After sterilisation, they are inserted, and the current must be turned on gradually until the strength of current passing amounts to 15 to 20 ma. per inch of positive needle. The immediate effect of turning on the current is to cause blanching and hardening of the tissues, especially around the positive needle, while froth and bubbles of hydrogen gas escape by the side of the negative needle, which also becomes loose. After a few seconds the tissues turn livid around the negative needle, when the current must be turned off and the needles taken out and reinserted in a fresh place, not too close, or sloughing is liable to ensue. This process is to be continued until the operator judges that enough has been done for one sitting, as sloughing of the tissues is to be avoided. Small nævi can often be satisfactorily dealt with at the first attempt, but larger ones may require several sittings. The process is a very painful one, and a general anæsthetic is necessary.

Unless the nævi are large, the two needles will be sufficient. Each should be held in a special needle-holder with a circular screw clamp to hold any sized needle. No current interruptor on the handle is necessary, or even advisable. If the needles are allowed to touch when inserted in the nævus the patient will get a sudden shock each time they touch and are released, and, though the patient is under an anæsthetic, such shocks are not advisable in the neighbourhood of the head and neck. Sometimes partially insulated needles are used, the needle being covered with a thin coating of rubber or shellac to within a third of an inch of the point. This is to avoid causing electrolysis of the skin at the point where the needle is inserted through it to reach a subcutaneous nævus. Such insulations are, however, rarely satisfactory, as they render it very difficult to insert the needle properly, and also prevent the proper sterilisation of the needle before using—a point which should always be attended to. A steel needle should never be used for the positive needle because of the indelible black stain which it always leaves upon the skin at the point of entry.

For large nævi a special needle-holder, devised by Lewis Jones, may be used, in which three, four, or five needles may be screwed into the holder, arranged like the prongs of a fork, alternately positive and negative. With this instrument the needles may be moved about as a whole within the nævus, and all parts of it brought under treatment.

Unipolar method.—This method is specially useful in those cases where the nævus is very small and involves the skin. As a rule, the negative pole is used for the active electrode. The positive pole should be attached to a flat plate electrode which may be applied around the patient's wrist, back of neck, or any convenient and accessible spot away from the head. The needle-holder is attached to the negative pole, and an ordinary sewing-needle may be used, as there is no danger of producing black spots in the skin with the negative needle.

Spider nævi and dilated venules on the face, forehead or nose are best treated by the unipolar method of electrolysis. The positive plate is folded close round one wrist, and a fine sewing-needle (No. 8) fixed in the screw clamp of the needle-holder attached to the negative pole. No current interruptor on the handle is advisable, as the current should be turned on before the needle is applied to the nævus. The needle must be sterilised each time before use ; but it is best not to do this by passing the needle through a flame, as in this way a fine deposit of oxide may be formed upon the point, which may leave minute black marks in the skin. If sterilised by heat first, it should afterwards be passed two or three times through a piece of carbolised lint to ensure the point being clean. These small nævi and dilated venules are very common on the face, especially after the age of thirty, and sometimes become sufficiently numerous or large to be worth removing. The centre point of the venule must be carefully looked for, and the needle-point steadily inserted to the base of the nævus and held there for from one to five seconds, the strength of current required being from ·5 to 1 ma. The immediate effect of the application of the needle-point is to cause the venule to contract and the red spot to disappear; great care must therefore be exercised and the hand held steadily so that the needle-point is not moved once it is applied.

The pain of this procedure is considerable, and cannot be borne by a great many persons without flinching. In that case it is advisable to anæsthetise the skin first by means of cataphoresis with cocaine, using a circular disc electrode for the positive pole, and applying it, after moistening it with cocaine solution, over the nævus. Using a disc electrode the size of a halfpenny, a current of 4 to 5 ma. should be passed through it for five minutes. If the area of skin under the pad is then tested with a pin or needle-point, it will be found comparatively analgesic to the surrounding skin owing to the cataphoretic action of the positive pole in forcing the cocaine through the skin into the tissues. It is to be remembered that cocaine, being an alkaloid, behaves like a base and is electropositive, and is attracted to the negative pole. It must therefore be applied to the skin under the positive pole in order to make it enter the tissues by means of cataphoresis. With the skin thus rendered partially analgesic, the pain produced by the electrolysis will be considerably diminished.

Cocaine

If there are many such small nævi and dilated venules on the face to be treated, it will not be possible to treat them all at one sitting. As a rule, not more than four punctures for electrolysis should be done without an anæsthetic. Although the immediate effect of puncture of the nævus is the disappearance of the red spot, there follows almost at once a slight swelling around the puncture, making it resemble somewhat the bite of an insect or the sting of a nettle. For the rest of the day the area treated will appear somewhat flushed and will feel hot, especially if cocaine has been used; and it will be well to dust the skin with a little fuller's earth or similar powder. It is a good plan to treat the two sides of the face on alternate days if several sittings are necessary. Some skins react more than others to the treatment, and in some all trace of the swelling will disappear in three days, while in others it may take a week before the skin looks quite normal again.

The effect of the electric puncture is to destroy the walls of the venules and to clot the blood in them by filling the tiny branches with bubbles of hydrogen gas, and the current should be sufficiently strong to show minute bubbles at the point of the needle if held for more than a couple of seconds. As a rule, with the tiny superficial dilated venules it is not necessary to insert more than the point of the needle.

It is important to remember to attach the needle-holder to the negative pole, for if the positive is used black indelible marks are left in the skin.

SUPERFLUOUS HAIRS AND MOLES

Large moles, as in the case of large nævi, are usually best treated by the actual cautery or by excision, as the length of time required for electrolysis is too great, and the result less satisfactory. Small moles of one-eighth of an inch across or less may, however, be well treated by electrolysis, and the resultant scar is less noticeable than with cautery or knife. Two needles should be employed for the larger ones—the positive needle, at all events, made of platinum—and the mole should be transfixed by the two needles at opposite sides, care being taken that the needles do not touch. A current of 5 to 10 ma. should be used for five to fifteen seconds. The part must be previously anæsthetised by a subcutaneous injection of cocaine, as the degree of anæsthesia obtainable by cataphoresis will not be sufficiently deep.

Superfluous hairs on the face, as on upper lip, chin, or in front of the ear, may cause considerable unsightliness in women, and may be conveniently removed by electrolysis. It is, however, a prolonged and somewhat painful process if the hairs are numerous. Considerable practice is necessary to perform the small operation of electrolysis of the hair follicles neatly and surely; for, as Lewis Jones says, it really amounts to a catheterisation of the hair follicles. The positive pole is attached to a flexible electrode and fastened round the patient's wrist or any other convenient exposed portion of the skin; while the negative pole is attached to a needle-holder, using a very fine platinum wire in the place of a needle. The wire, blunt-ended, is better than a pointed needle, for it is less likely to penetrate elsewhere than into the hair follicle. The patient reclines with the head thrown back, in a good light; three cells of the battery are turned on, sufficient to give a current of from 1½ to 2 ma. when the wire is inserted. The hair is gently pulled with the left hand, and the platinum wire is passed as close to the root of the hair as possible so as to enter the hair follicle for a distance of about one-eighth of an inch. It is held there for about five seconds, small bubbles of hydrogen gas escaping beside the root of the hair; and the hair should then be pulled out by using gentle traction. The pain is certainly sharp, but can be borne, and cocaine cannot in most cases be applied. Very slight scarring ensues, and, if carefully done, it is practically invisible after a week or two. Several hairs close together should not be attacked at one sitting, the whole area to be done being gone over equally, the number done on each day depending on the endurance of the patient and varying from five or ten to three or four times that number.

STRICTURES

The destructive action of the negative pole has been made use of in the electrolysis of strictures of the urethra, nasal duct, and œsophagus, and lachrymal obstruction. Obstruction at the punctum or in the canaliculus leading to the lachrymal sac has been cured by using the negative pole attached to a fine platinum probe passed into the punctum and along the canaliculus, using a current of 2 to 3 ma. Traumatic stricture of the œsophagus, due to cicatricial contraction after swallowing corrosives, has also been said to be relieved by electrolysis with the negative pole attached to a small olive-shaped metal flexible bougie covered with rubber or celluloid nearly up to its end. Not more than 3 or 4 ma. should be employed, for ten minutes at a time on alternate days.

FIBROIDS

Uterine fibro-myomata have been treated by Apostoli and his followers by means of intrauterine galvanocausis. The method is troublesome and prolonged, numerous sittings being necessary; and in the majority of cases the condition can be dealt with better by surgical operation. Certain cases, however, have been considerably improved by the intrauterine galvanisation, especially hæmorrhagic fibroids, the bleeding becoming arrested and the fibroids diminishing in size.

The method is as follows: An intrauterine sound, made of platinum, is passed into the uterus, under antiseptic precautions, and is protected by an insulation covering from the vaginal walls and external parts. This, the active electrode, is attached to the positive pole, while the indifferent electrode, or kathode, is applied to the anterior abdominal wall. The kathode was formed by Apostoli of moist china clay, but this is unnecessary. The kathode must be of large surface, and should consist of a flexible leaden plate 10 inches by 7 inches. The best way to apply this to the abdominal wall is over a sheet of wetted cotton-wool. This should be cut a little larger than the metal electrode and thoroughly wetted in dilute hot saline solution, and then applied uniformly over the lower part of the abdomen, and the metal electrode carefully fitted over it so as to be in complete apposition with the wet wool over its whole surface, but yet not touching the skin anywhere. Great care must be taken before turning on the current that all the screw connections of the wires to the battery and the electrodes are quite tight, because with the heavy current used in this treatment any sudden interruption due to a loose wire connection or any other cause would give a serious shock to the patient. A strong battery is necessary to provide the current, and when the electrodes are in position the current must be turned on gradually until the galvanometer indicates 50 ma. This current is allowed to flow for six minutes, and is then gradually turned off and the uterine sound withdrawn, a vaginal douche completing the operation.

The process should be repeated on alternate days, the intensity of current being raised on subsequent occasions to 60, 80, or even 100 ma. It is most important, during the passage of this heavy current, that the patient should keep absolutely still, and that neither the uterine sound nor any portion of the apparatus should be moved needlessly, on account of the danger of interrupting the current and thus giving the patient a severe and perhaps dangerous shock. After the completion of each application the patient should rest on the couch for half an hour before being allowed to walk about.

ANEURYSM

Electrolysis has been used in the treatment of aneurysms of the larger arteries, as the subclavian, innominate, and even the thoracic aorta. Two platinum needles are inserted, with antiseptic precautions, through the wall of the sac, from 1 inch to 2 inches apart, attached to needle-holders and the two poles of the battery. A current of 30 ma. is gradually turned on for ten minutes, then gradually turned off and the needles withdrawn, the punctures being sealed with collodion gauze. The object of the treatment is to cause clotting around the two needles, and so strengthen the wall of the sac and gradually obliterate the pathological dilatation of the vessel. The clot is, however, of loose consistence and of little value in an aneurysmal sac with a fierce current of blood constantly running through it. The method would have more chance of success in an aneurysm of a smaller artery, such as the femoral, brachial, or radial. In this case the artery could be compressed on the distal side of the aneurysm while the electrolysis was being done, and also for two hours after, in order that the resultant clot might not be washed away as soon as it was formed.

+E. at the head is [illegible] [illegible]
with flannel &c
−E. at the [illegible] , [illegible] [illegible] [illegible]
[illegible]

CHAPTER IX

ELECTRIC BATHS

THE GALVANIC ELECTRIC BATH

This treatment is applied by immersing the patient in a warm bath up to the neck, and passing the current through the bath from end to end between two large metal electrodes. The positive electrode is placed behind the patient's back, and it must be covered with flannel or other material to prevent the metal from touching the skin. The negative electrode at the foot of the bath need not be so protected on account of the thick skin on the sole of the foot. Published calculations of the proportionate amount of current that passes through the patient's body, as compared with what is wasted by passing through the water only between the electrodes, have taken as their basis the comparative resistances of the volume of the water in the bath and the resistance of the body, and it is asserted that only about one-eighth or less of the total current is available for treatment of the patient. My own experiments, however, judging from the intensity of the sensations felt and the degree of muscular contractions produced by reversals of the current, indicate that only two-thirds of the current on the average are wasted, one-third passing through the patient's tissues, and that the higher the voltage used the greater is the proportion of current that passes through the body. However, to pass a current of 50 ma. through the patient's body in the bath, it will be necessary to employ a total current of at least 150 ma. Now, it is practically impossible to obtain currents of this strength from a primary battery of wet or dry cells, and unless a battery of thirty accumulator cells, giving 60 volts, is available, it will be necessary to employ the main electric lighting currents for the purpose.

The best method is undoubtedly to use a battery of thirty accumulator cells, costing from £15 to £20. These will give a pressure of 60 volts, and the current can be conveniently applied by means of a shunt resistance or rheostat. With this source of direct current, the ordinary enamelled full bath, with its water-taps and waste-pipe, can be used, as there is no possibility of any danger from leakage of current to earth; nor will there be any danger of the patient accidentally touching an electric-light switch or water-tap while in the bath. This method may be said to be "foolproof," and such a galvanic bath may with perfect safety be manipulated by a nurse or other attendant, or even by the patient, after the way to use it has been thoroughly explained. If the house is wired in connection with the direct current electric-lighting mains, the accumulators need never be moved, and can be recharged through lamp resistances whenever necessary, when the bath is not being used, using a lock switch to ensure cutting off the main contact with the accumulators when the bath is being used. Another safe method is to drive a small DC dynamo by an electric motor. The dynamo must be wound to produce half an ampère at 50 volts, while the motor to drive it may be worked by either the alternating or direct current from the main. This method will be very suitable for an institution or a hospital.

It is possible to make use of the direct current from the main for giving the galvanic bath; but special experience is necessary, and the expert must be present during the whole time that the bath is being given. The bath should be made of porcelain, and must have no direct connections with waste or water pipe. Moreover, no water-tap or electric-light switch must be within reach of the patient when in the bath, or a fatal shock might result. This may happen in the following way: one of the poles is generally earthed at the power-house, as in the Marylebone supply, and therefore, when the bath is connected by wires through a shunt resistance to a wall-plug or other electric-light switch, if the pole that is connected to the zero or right-hand end of the shunt resistance is not the same as that which is earthed at the station, then there will be an immediate rush of current between the waste or water pipe which is connected to earth and the wires of the apparatus, and the patient may, or may not, feel the effects of this powerful current, according to his position in the bath with relation to the line of this current. Even if neither pole is earthed at the station, there is usually sufficient leakage to earth from the cables to make such an earth current extremely dangerous. If, for instance, while immersed in the water he were to touch either the cold or the hot-water pipe, he would get a dangerous shock. The operator should, therefore, always test his apparatus after connecting it to the wall-plug or other source of the electric-lighting current, to ascertain whether the pole connected to the zero end of his shunt resistance is the same as that which is earthed at the station. When that is so, there can be no danger of any accidental shock, if the patient should touch a water pipe, or even if the bath itself is connected directly to earth through the waste-pipe.

The method of testing will be for the operator, after connecting his shunt rheostat to the wall-plug, to turn on the switch and then lightly to touch with the dry fingers of both hands a binding-screw of his apparatus and a water-tap. If he feels a strong burning sensation, then the earthed pole is not the one which is connected with the zero of his shunt rheostat, and to put matters right he must now reverse the two-pin wall-plug, so that he reverses the pole connected to the zero of his rheostat. When this position of the wall-plug has been ascertained, it should be so marked that it may always be inserted in the same way. With the sliding contact spring also at zero, he may now touch with impunity, even with wet hands, a binding-screw and water-tap at the same time; there can be no danger of any shock to the patient from an earth current, and the available current for the bath will be entirely controlled by the sliding spring contact. With a properly enamelled bath, and the enamel not chipped anywhere below the surface of the water when filled to the desired height, the orifice of the waste-pipe at the foot end of the bath will be the only metallic contact with the water to "earth," and it will be possible for an expert to make use of such an ordinary full bath as a hydro-electric galvanic bath, using the direct current electric-light mains as the source of the supply. Under these conditions the orifice of the waste-pipe will act as the footplate, and only one wire and electrode joining the shunt rheostat to the bath is to be used.

The method of using the main current in this case is as follows: assuming that an ordinary platinoid wire shunt rheostat is used, with safety lamp, switch, galvanometer, and current reverser in the circuit, the first point to ascertain is which pole is earthed at the station, as upon that depends whether the footplate—that is to say, the orifice of the waste-pipe—will be positive or negative. First see that the two-pin wall-plug is inserted properly, so as to avoid all danger of shock from the earth current, as above described; then take a basin of water, attach one wire to either of the two binding screws of the rheostat, and let the other end of the wire dip in the water. Take another wire, and let one end dip into the water close beside but not touching the other wire, while its other end is held in contact with a water or gas-tap. The sliding contact spring is then pushed along some distance, and the two ends of the wires dipping into the water are watched. Bubbles coming off one of them will indicate that to be the negative pole. If neither gives off bubbles—that is to say, if no current is passing—then switching over the current reverser will at once start the current. If the wire that is earthed is negative, then the bath electrode and its wire must be attached to the positive binding-screw of the rheostat. (N.B.—The sign of the rheostat binding screws will vary according to the method of insertion of the two-pin wall-plug, and must be determined beforehand for the particular position of the wall-plugs that are being used at the time.) Even now, although a current is passing, a current which increases in intensity as the sliding spring contact is pushed further along, yet the galvanometer may indicate no current because the galvanometer circuit is only connected with one of the poles. If this is the case, the wire to the bath electrode must be taken out and attached to the other binding screw of the rheostat, and the current reverser switched over. All the wire connections are now in order, and the galvanometer will indicate accurately the amount of current that is being used in the bath. This method is perfectly safe, and no shock from an earth current is possible, since the earthed pole is the same as that which is connected to the zero end of the rheostat, so that it comes to the same thing whether the zero end of the rheostat or a water-pipe is connected to the bath as one of the poles.

As the description of the method given above will show, it will require some electrical knowledge to make use of an ordinary bath for giving a galvanic hydro-electric bath, when using the electric-lighting mains as the source of the electricity. With that exception, the only point against it is that the direction of the current cannot be reversed, but will depend entirely on whether the earth current is positive or negative. The earthed pole will not necessarily be the same for all the houses in the same district; neighbouring houses, or houses on the opposite sides of the same street, may differ in the sign of the earthed pole, and it must, therefore, be determined separately for each house.

The difference arises from the fact that some districts are supplied on the "three-wire system"—*e.g.*, Marylebone, where the two outer wires have a difference of potential of 480 volts, while each outer wire differs from the middle wire by only 240 volts. Therefore, the middle wire will be positive to one outer wire, and negative to the other. Some houses will receive their current at 240 volts from the middle wire and one of the outer wires, while an equal number will receive their electric supply from the middle wire and the other outer wire. Thus, if the middle wire is the pole that is earthed at the station, the earthed pole will appear to be positive in some houses and negative in others. The stronger current at 480 volts is used for power purposes for driving motors of five-horse-power and upwards.

With a properly insulated porcelain bath, the waste-pipe does not connect directly to the bath, but to a porcelain or earthenware gully into which the bath discharges. The water-taps are placed at a little distance from the bath and are covered with flexible rubber hose-pipe, through which the bath is filled. Even with these safeguards against any accidental leakage to earth, care should always be taken to see that the two-pin wall-plug or other attachment of the shunt rheostat to the electric-lighting mains is so fixed that the pole that is earthed at the station is the same as that attached to the zero end of the rheostat, so that when the current is switched on and the sliding spring contact is also at zero, no shock is felt with wetted fingers, one placed on one of the binding screws of the rheostat and the other on a water-tap. If this precaution be taken, then there is no possible danger of an accidental connection of the bath to earth while the patient is still in the bath. This, for instance, may easily occur by discharging the bath water through the waste-pipe before the patient has got out of the bath, the column of water thereby establishing an earth connection; or, again, by turning on some more hot water after the patient has got into the bath. If the rheostat has been arranged as described above, so that the zero end corresponds with the earthed pole, the liability to shock will be lessened. The risk, though not of a dangerous nature in that case, cannot be entirely done away with, because the sudden earthing of one end of the bath by means of the incoming or outgoing stream of water must interfere with the strength of the current passing between the two electrodes already in the bath, since an alternative path for the current is afforded, and thus the sudden diminution of current passing through the patient will be felt as a shock, which would be decidedly unpleasant when 20 ma. and more were being used. With an insulated porcelain hydro-electric bath it is a good plan to have a switchboard arranged in connection with four pairs of electrodes along the sides of the bath (positive on one side and negative on the other), so that more current can be concentrated, if necessary, through the legs or lower half of the body.

This method of applying general electrification to the whole body by means of the hydro-electric galvanic bath will be found exceedingly useful in the treatment of lumbago, chronic sciatica, and chronic muscular rheumatism; and the effect of this form of application of the galvanic current is notably to diminish the pain of a neuritis. It will also be found of decided value in certain states of debility with anæmia, in palpitation and tachycardia, Graves's disease, Raynaud's disease, and multiple neuritis. In cases of local neuritis in which it is desirable to stimulate muscular contractions, the hydro-electric galvanic bath is less desirable than local treatment of the limb with galvanism by the labile method. When administering the hydro-electric galvanic bath the temperature of the water should be about 100° F., and the patient should not be kept in the bath on the first occasion for more than ten minutes, though this may be increased with advantage on subsequent occasions to twenty minutes.

[illegible]

Temperature 98 to [illegible]
Length in bath

FOUR-CELL OR SCHNÉE BATH

It is often inconvenient for a patient to take a full bath, and a fair substitute for the full bath treatment in many conditions, especially in neuritis affecting the limbs, is the four-cell bath, or Schnée bath. This is an arrangement of four small baths, one for each limb, each of which is fitted with a carbon or copper electrode connected by insulated wires to a central switchboard. The baths are made of porcelain or earthenware, the foot-baths being sufficiently deep to hold the leg up to the knee, while the arm-baths are about 6 inches deep by 8 inches wide, and long enough to take the forearm from the elbow to the tips of the extended fingers; that is to say, 20 inches inside measurement. The two arm-baths are fixed at a convenient height on the arms of a stout chair, so that the patient can sit in the chair with the forearm on each side immersed up to the elbow in the bath, and the feet and legs placed one in each of the foot-baths. The baths are filled with hot water, in which may be dissolved certain salts for

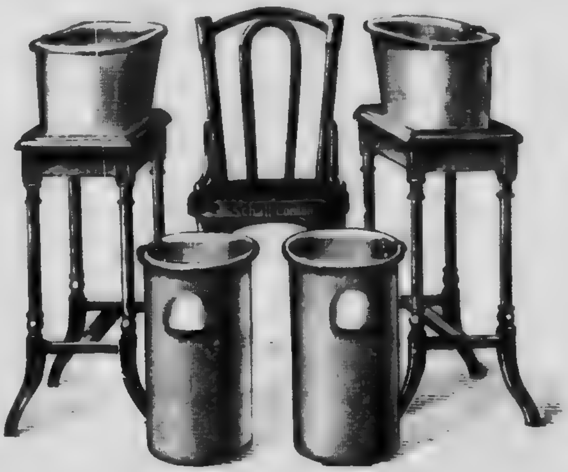


Fig 13. Simple form of four-cell or Schnée bath.

medicated baths, such as lithium chloride for the treatment of gouty joints. The switchboard is fixed at the back of the chair, and is connected to the battery, which may be either galvanic, faradic, single or three-phase, sinusoidal, or Leduc alternating. The switchboard is so arranged that the two arm-baths are connected to the positive electrode, and the foot-baths to the negative, or *vice versa*. This method of applying galvanism has certain advantages over the full galvanic bath, besides the saving of trouble in the matter of the patient undressing, for only the boots and stockings need be taken off and the sleeves turned up above the elbow. In this form of application of the current there is no wastage of electricity, as all the current that is used passes through the limbs and body of the patient. The strength of the current should, therefore, range from a minimum of 7 or 8 ma. to a maximum of 25 to 30 ma., though with this stronger current great care must be taken not to break or interrupt the current, and all the connections of the wires must be carefully attended to and screwed up tightly, as should one connection slip or break the patient will get a violent shock. With strong currents, moreover, the skin is apt to get sore at the water level. If only the legs require treating, the arm-baths need not be used, and one leg-bath can be made positive and the other negative. With this arrangement a mechanical interruptor or alternator can be inserted into the circuit so as to interrupt or reverse a current of 5 to 8 ma. once a second or so for the treatment of wasted muscles due to neuritis or other causes.

LOCAL ARM- OR LEG-BATHS

Two, three, or four of the cells of the Schnée bath may be made use of. Thus, one arm and leg may be treated for hemiplegia in an arm- and a leg-bath by the sinusoidal current, or one arm and both legs by the three-phase current; or both arms in the two arm-baths by galvanism for rheumatoid arthritis or for Raynaud's disease. If one limb only requires treatment, such as one arm by galvanism for writer's cramp or for neuritis, the two electrodes may both dip into the water, one at each end of the arm-bath, or one flexible electrode may be fastened above the elbow to the arm above the level of the water. If both electrodes dip into the water, the positive electrode should dip into the water behind the patient's elbow, and the negative or kathode near the fingers. The strength of the current passed through the bath should be about 20 to 25 ma., though it is to be remembered that not the whole of this amount passes through the arm itself—probably only about one-third.

This point I have tested in the following manner, which, if more open to errors of inaccuracy, is certainly more practical as regards its application to the treatment of patients than the published calculations of the comparative resistances of the body of the patient and of the water contained in the bath. These latter calculations seem to show that the body of the patient carries only one-tenth of the current passing between the electrodes in the bath. I partially filled an arm-bath to a depth of 3 inches with warm water at a temperature of 100° F., and placed the positive electrode, a flexible metal plate covered with chamois leather, at the bottom of the water. The negative electrode, exactly similar to the other, after being thoroughly wetted, was applied tightly to my arm above the elbow, and I then placed my hand in the water spread out over the positive electrode, the water just covering the hand entirely. The current was then turned on gradually until a definite strength of sensation was experienced in the hand, and the number of milliampères was noted by my assistant. The two electrodes were next placed vertically in the water at the ends of the bath, the negative at the elbow end, and then I placed my forearm in the bath so that the water covered it completely up to the elbow, the fingers just touching the positive electrode. The current was then, as before, turned on gradually until I noted that the degree of the sensation in the hand appeared to be the same as before, my assistant noting the reading of the galvanometer. The two readings were 6 and 18 ma. respectively. The experiment was again repeated, with a stronger degree of sensation for comparison. The readings on this occasion were 12 and 35 ma. It is thus clear that a larger proportion of the galvanic current passing between the electrodes affects the tissues of the forearm than the published calculations of the comparative resistances of the patient's body and of the bath water would lead one to expect, and I feel assured that the statement that only one-tenth of the current used is perceived by the patient rests on insufficient grounds and faulty deduction.

If faradism be used instead of galvanism for the comparative test, it will be found that a very small approximation of the secondary coil to the primary is needed to produce the same sensation in the hand and the same degree of muscular contraction of the forearm when the whole forearm is dipped in water between the two electrodes, as when the hand only is in the water and the other electrode is fastened above the elbow. Thus, in my own case, with the hand only in water and one electrode fastened above the elbow, I noted the strength of sensation when the coil was distant 75 mm. from the primary. With the whole forearm immersed, and both electrodes dipping in the water, one at the elbow and the other at the fingers, the same degree of sensation was experienced when the secondary coil was distant 67 mm.—that is to say, only about a quarter of an inch nearer the primary. Using the primary faradic current instead of the secondary, the same degree of sensation and muscular contraction was experienced with the soft iron core withdrawn 62 and 50 mm. respectively; that is to say, when the whole forearm and the two electrodes were in the water the soft iron core of the primary had to be pushed in only half an inch to strengthen the sensations to the same degree as when only the hand was in the water, and the other electrode was fastened to the arm above the elbow.

THE LEDUC CURRENT

Professor Leduc of Nantes has devised an apparatus by means of which an electric motor is made use of in order either to interrupt or to reverse the direction of a constant galvanic current, at varying speeds. The current that is used to drive the motor is quite separate from that which is used in the transforming portion of the instrument, and the latter current may be supplied either from a constant current battery, or through proper resistances and a volt-selector from the direct current of the electric-lighting mains. The motor may be driven by either alternating or direct current, according to its design, or even hand-power may be used to rotate the transformer by means of a wheel and suitable gearing. The effect of the interrupted or reversed galvanism on muscle is to cause tetanic contractions, somewhat similar to those produced by the faradic current, though the intensity and quality of the effect on sensory and motor nerves differs somewhat according as the current is interrupted or reversed, and also according to the proportionate duration of the contacts and to the speed of the motor (Fig. 14). When the motor is used to *interrupt* the galvanic current, the speed of the interruptions can be graduated by resistances in the motor circuit from about 10 to 160 per second, each revolution breaking the current four times. By means of altering the position of the collecting brushes the duration of contact can be lengthened or shortened at will, so that for each quarter-revolution of the motor there may be obtained either a momentary application of the current, and a long interval in which no current is passing, or a long contact and a momentary break of the current, or any gradation between these two extremes, such as half contact and half interval. It is clear that when the motor is running and producing interruptions in the galvanic current, the average current as indicated by the galvanometer will vary according to the relative durations of contact and interval. Thus, with the machine tested, when the motor was at rest, a current of 14 ma. was arranged to flow through a fixed resistance ; the motor was then started, and it was found that with the brushes arranged for the longest contact the current fell to 12 ma., while with a contact of one-quarter (the galvanometer indicated only 3.5 ma., the speed of the motor making no difference.

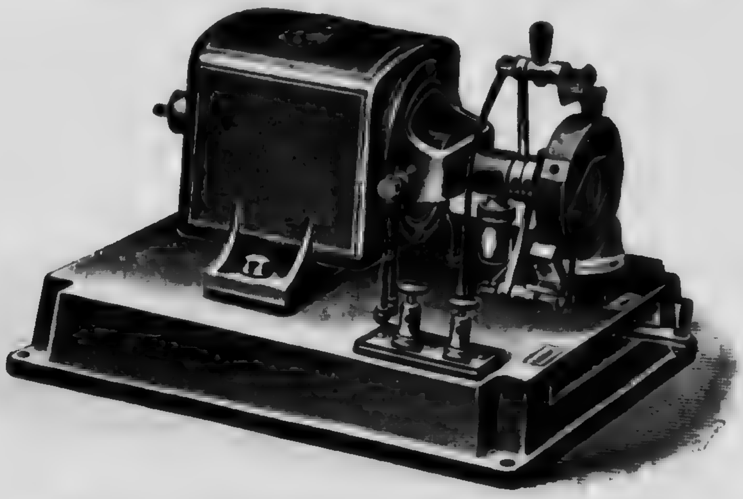


Fig. 14.—The Leduc motor, with interruptor.

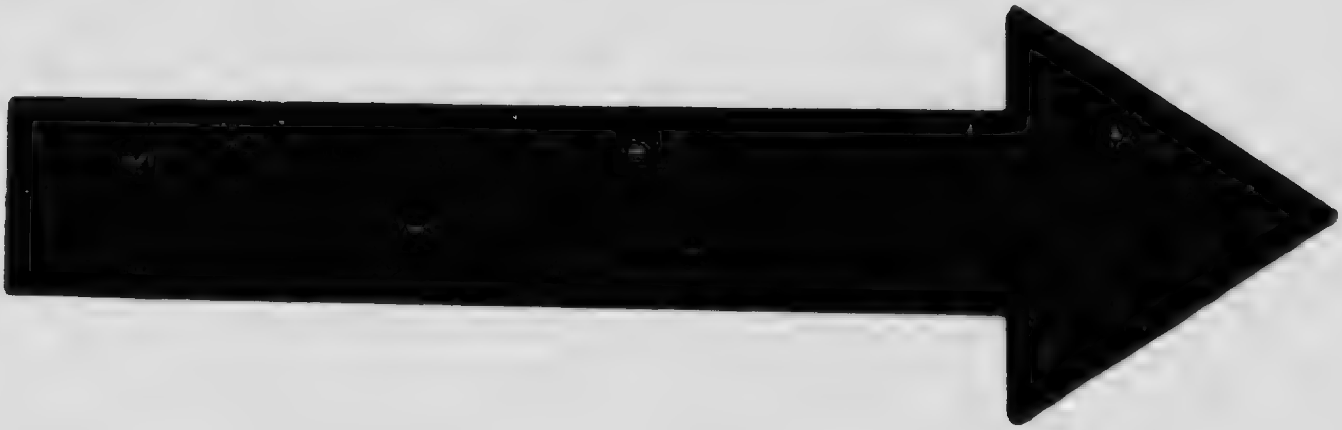
Motor effects of interruptions. — The strongest muscular contractions are produced by arranging the brushes for one-tenth contact, and nine-tenths interval with no current, and a slow speed of the motor, giving 30 to 40 interruptions per second, with a descending current along the limb. This was tested with wet electrodes upon the muscles of the forearm, and using short contact and slow speed of the motor, giving about 1,800 interruptions per minute, the maximum current borne was 15 ma., being about equal in sensory effect to 18 ma.

without interruptions. The muscular effect is much stronger at the kathode, and as the period of contact of the brushes was increased, so the muscular and sensory effect diminished, while at the same time the current increased from 1·5 to 12 ma. This diminution of the effect with long contact is more noticeable at high speed than at low speed, when the diminution is only slight, and it is noticeable both at the kathode and the anode. With maximum contact and using a current of 1 ma. or a little less, the muscular effect in the thenar eminence is only just perceptible at the lowest speed, and is diminished to the vanishing point at high speed. With a current of 2½ ma., there is fair tetanus of the thenar eminence at the lowest speed, which does not disappear entirely at the highest speed of the motor—160 interruptions per second. With short contact, strong tetanus of the thenar muscles is produced by the kathode with a current of only 1 ma. at low speed. With the high speed the contractions are less.

Sensory effects of interruptions.—On placing one electrode on the eyeball in order to stimulate the retina, and the other on the wrist, using a weak current, it was found that with both kathode and anode the retinal effect was stronger with very slow interruptions and long contact than with short contact; but with more rapid revolutions of the motor, producing 1,800 to 2,000 interruptions per minute, the retinal stimulation appeared stronger with short contact. The total sensory effect on the retina, however, diminished as the speed of the motor increased, so that with 8,000 interruptions per minute a current, which produced bright flashes of light in the eye with a slow speed, was not now perceptible.

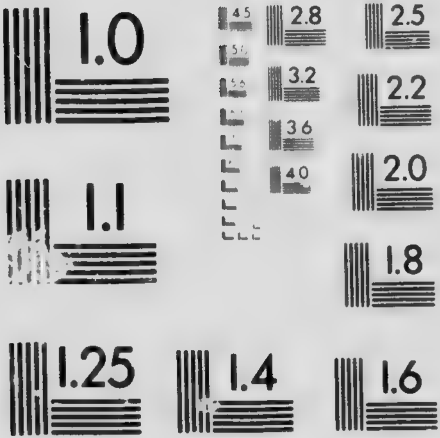
Reversals of current.—When the Leduc motor is used to produce reversals of current, a different wheel and arrangement of the brush contacts are used from those for the interruptions. There are four brushes, and each revolution gives two reversals of the current. The proportionate duration of contact, and of interval in which no current is passing, may be altered by moving the position of the brushes. The current is passed through a galvanometer before it is led to the reverser, so as to indicate the average current passing. If the galvanometer were included in the circuit between the reverser and the patient, the galvanometer needle would remain at zero.

Motor effects of reversals.—A current of 1 ma. or even less at a slow speed of the motor gives a fair tetanus of the muscles of the thenar eminence with maximum duration of the contacts, being a very much stronger contraction than that produced by the kathode when interruptions with maximum contact, and of the same strength of current, are used. Of course, when reversals are being used, there will be no difference in the action of the two electrodes, since each is alternately kathode and anode as the current is reversed. As the speed of the motor is increased, so the muscular effect with reversals is increased up to the fastest speed of the motor—about 80 reversals per second. With apparatus specially arranged for the production of very rapid reversals of the current, it has been shown that muscular excitation increases with the speed of the reversals up to 2,000 or 3,000 per second, and then diminishes until all signs of contraction disappear at a speed of 10,000 alternations per second, when the phenomena of high frequency currents commence to appear. With the particular instrument tested, I arranged a current of 14 ma. to pass through a fixed resistance with the motor at rest; this was diminished to 13.5 ma. when the motor was started at slow speed reversals and maximum duration of contact, the current falling to 11 ma. when the motor was run at its highest speed of 80 reversals per second. With short periods of contact and long proportionate interval, the average current indicated by the galvanometer will fall considerably. When the period of contact is reduced to one-tenth of the interval between the contacts, the contractions, though



MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc
1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

powerful, are said to be much less painful than with a corresponding strength of faradism.

If we compare the tetanic effects upon the limb muscles of interruptions of a galvanic current with those produced by reversals, we find that interruptions of a descending current from the anode on the upper arm to the hand placed on the kathode, using only one-tenth contact and 40 interruptions per second, gives far stronger contractions than we obtain from reversals, using maximum contact, and the same strength of current shown on the galvanometer. Thus, placing the forearm in water in the arm-bath, with the anode behind the elbow, and the kathode at the fingers, the current was turned on until 26 ma. were running steadily through the bath. Then starting the motor, using interruptions with one-tenth contact, strong tetanus of the forearm muscles was produced, though only 2½ ma. were now indicated on the galvanometer. Approximately, to obtain the same degree of muscular tetanus with reversals, using maximum contact, required a current of 24 ma. shown on the galvanometer. Now, with maximum contact, reversals give stronger contractions than interruptions do, and with one-tenth contact, reversals may also prove the stronger.

For general stimulation of the muscles and tissues, and for muscle-testing, rapid interruptions or reversals of a weak galvanic current by the Leduc motor—with the brushes arranged for one-tenth contact and nine-tenths interval with no current—may prove exceedingly useful, and should supersede the faradic coil for all work where accuracy is desired. With the faradic coil the current curve is irregular, and its milliampèrage unknown.

Although the Leduc motor, using interruptions, or preferably reversals, may be used for muscular stimulation, rapid interruptions have no effect in producing contraction in degenerating muscle in cases of nerve injury. Such degenerating muscle will give well-marked sluggish contractions to slowly interrupted or slowly reversed galvanic currents, but when the frequency of the interruptions or reversals exceeds two per second, the strength of the muscular contractions diminishes to *nil* as the speed of the interruptions or reversals is increased.

Sensory effects of reversals.—Testing the retina in the same way as with the interruptions, and using the same strength of current, the brilliance of the effect on the retina is very much more powerful, with maximum duration of contact, than with the interruptions; and whereas with the latter the sensory effect diminishes with the increase of speed of the motor, with the reversals the effect on the retina increases up to a speed of 30 per second, and then diminishes to the vanishing point at 80 per second, using a current which gave very great brilliance with 30 reversals per second.

On the whole, the sensory effects of the rapid reversals of current with the Leduc motor, with maximum duration of contact, upon the skin and muscles are much greater than with a faradic current which produces the same degree of muscular contraction, the Leduc reversals of a galvanic current being distinctly more painful than a corresponding strength of faradism, especially when the motor is run at a high speed of 80 reversals per second, using maximum duration of contact; but with very short durations of contact the contractions, though efficient, are said to be less painful than the corresponding strength of faradism.

With very high speeds of alternation the sensory effects on skin and muscle both disappear, as is the case with the motor effects when high frequency phenomena commence.

Electric sleep.—Leduc has made experiments on the inhibitory action of rapid interruptions of the current upon the brain cortex in dogs and rabbits. The head is shaved, and a large kathode, covered with cotton-wool and wetted with saline, is applied to the top of the head, while a large anode is fixed over the lower spine. The best results were obtained by using interruptions of 150 to 200 per second, with the brushes arranged for as short a contact as possible, and a pressure of 12 to 30 volts, giving currents of 2 to 10 ma. A rheostat without self-induction is placed in the circuit to regulate the voltage. By this addition, convulsions and arrest of the respiration, and evacuation of the sphincters, are avoided. Starting the current causes no pain, the animal falling on its side quietly into a condition of deep narcosis, without exhibiting the least sign of pain or discomfort; and on the cessation of the current the animal awakens instantly, without any sign of pain, fear, or fatigue. In other experiments on dogs, general convulsions were produced as the current was gradually strengthened; and then, on diminishing its strength, a state of narcosis and anæsthesia persisted as long as the current was applied, the animal recovering at once as soon as the current was stopped.

Local anæsthesia of part of a limb may be obtained by placing the kathode upon the course of a superficial nerve. This produces a strong sensation of tingling, and complete insensibility of the corresponding skin-area.

Should further experiments show this method of inducing anæsthesia to be certain in its action, without any ill after-effects, an immense field in the treatment of neuralgia and neurasthenia, and perhaps even in the induction of surgical anæsthesia, may be open to it.

DANGERS FROM ELECTRIC-LIGHT MAIN AND OTHER HIGH TENSION CURRENTS

The majority of accidents from electric shock occur amongst the workers of the electric lighting companies, either from accidental contact with live wires when engaged in repair work on the cables or in changing transformers, or from accidental contact with parts of the switchboard in the power house. Workmen by no means always observe the rule to wear rubber gloves when doing work on the cables, and they may either receive shocks by getting a "short" between two wires at different pressures, or else, when standing on damp ground, contact with a live wire will afford a path through the body to "earth" for the passage of a heavy current, which may easily be fatal. Inside buildings the current is never at a higher pressure than 240 volts, except for the driving of motors of one or more horse-power, when it may be as high as 480 volts. Even low voltages of 100 to 200 volts, such as are commonly employed on electric-lighting circuits within houses, are by no means altogether devoid of danger to life, should a good contact to earth be established by the body to a live wire. Indeed, so low a voltage as 70 has been fatal in a chemical factory in Germany to a workman who was standing with bare feet in an alkaline solution, and thus afforded an ideal contact with "earth."

The especial dangers with electric baths have already been alluded to (*see* p. 252), whether the current is direct or alternating. The bath should be of porcelain, and not only should it be entirely unconnected by water-pipes to earth, but all water taps and pipes and electric-light switches should be quite out of reach of a patient in the bath. The bath should be filled with water through a rubber hose-pipe attached to the water-pipe; but, once the patient is in the bath, no more water should be turned on. With some direct current installations, in which one of the poles is intentionally earthed at the power-house, it is possible to arrange the apparatus so as to avoid the possibility of shock through an earth current (*see* p. 252). Even with the best and most perfect method of insulating the bath and patient from earth currents, when using the direct current from the main for electric baths there is always the possibility of a sudden alteration in the voltage, which will cause a shock to the patient that might well be dangerous if large currents in the full bath were being used. A sudden fall in voltage in an electric-light supply will be indicated by the incandescent lights suddenly losing brilliancy and glowing a dull red; while a raising of the voltage produces a sudden increase in brightness of the lamp. Or the supply may fail altogether for a few seconds, or even for minutes at a time, all of which accidents have been unfortunately familiar to us who live in the Marylebone district of London. Still another possibility of shock when using the direct main current for treatment is the liability of a sudden switch-over at the power-house from one machine to another, or from the dynamo to a battery of accumulators. For these various reasons I do not consider it safe to use the direct main current for hydro-electric bath treatment; and if the direct current is required, it should be supplied from a special battery of accumulators. These may be charged from the DC main, but a safety switch should be provided, so that the current from the accumulators cannot be turned on to the bath until the main current has been first switched off.

In **alternating currents** the position is quite different; no dangerous shock will be produced by a sudden fall in the voltage or cessation of the current, or by changing over from one machine to another at the power-house; moreover, absolute safety with regard to earth currents is attainable by the simple means of passing the main current through a static transformer, which for treatment purposes is most conveniently built as a sledge-coil.

The direct current from the main may, therefore, be used safely for all forms of labile treatment, for muscular wasting, etc., in which the strength of the current is not likely to exceed 15 ma. For stabile applications, such as electrolysis of hairs, naevi, etc., for cataphoresis, or for neuralgia, the main current is less suitable, but still may often be employed, the only danger being the possible one of a somewhat unpleasant shock if the current be suddenly interrupted. When larger currents are employed, such as galvanisation for sciatica, or the Apostoli treatment for fibroids, or especially in the hydro-electric bath, in my opinion the main direct current is unsafe, and should not be used.

Nearly all accidents from shock or burning with main currents occur to persons engaged in the work of cable repairing, transformer changing, or in other work about the power-house or transmission lines. The large majority of fatal accidents occur with voltages of 1,000 and upwards, which has given rise to the idea that the alternating current is more dangerous than the direct. It is not the type of current that causes the difference in the severity of injury, but the difference in voltage, the direct current seldom being met with at a higher voltage than 550. This latter strength of voltage will not give a shock through ordinary dry clothing, and it has been demonstrated that a person may sit upon the third rail of the Central London Railway, which is electrified with direct current at 550 volts, and rest his hands upon the outer rails, which carry the return circuit, without getting a shock. If the clothing were wet with rain or perspiration, a severe shock might, and probably would, be received. Unless the person remained in contact with both conductors, it is probable that a shock at this voltage would not be fatal, though it is to be remembered that at the comparatively high voltages of the main supply, muscles behave differently from what we find in the physiological laboratory with muscle-nerve preparations and weak constant currents. It has often been found that contact with the main direct current tetanises the muscles; and if a person should unfortunately catch hold of a live wire at a voltage of 200, when his feet were in good contact with earth, as when standing in water, he might be unable to leave go, and the sudden rush of current would very quickly be fatal. In this way a man was killed in the street by becoming entangled in some telephone wires which in a snowstorm had fallen down across the trolly wire of a tramway, the ends trailing in the street and having become "alive" through contact with the trolly line at 300 volts.

When a workman gets a "short" by simultaneous contact with two wires of a circuit at different voltages, the danger will differ according to the method of contact. If one hand or arm, or one leg has touched both the wires, the result is never fatal if the shock is momentary, as the current is concentrated between the two points of contact in the one limb, and the man gets off with a burn, and nothing worse than faintness and weakness, though this is often succeeded by hysterical symptoms of various intensity and duration. If both hands form the contact, or one leg and one hand, then the results may be much more grave, and a fatal result is not rare, the man being killed, perhaps instantly, the heart being arrested in fibrillary contraction. Some experiments on animals by Prevost and Battelli, with alternating currents at different voltages, showed death from heart failure with shocks at 120 volts pressure; with high tension currents at 1,200, 2,500, and 4,800 volts, tetanus and convulsions were produced, and respiratory failure, but the animals could be saved by artificial respiration. In America, where criminals are electrocuted for murder, it has been found more than once that the first shock at 1,200 to 1,500 volts has not been fatal, though convulsions and burning of the skin were produced during the period of contact. A case has been recorded in America of a man receiving during several seconds a current at the pressure of 20,000 volts. He was standing close to the main switchboard of the power house, when by some accident he was knocked against it and the current arc'd across to one shoulder, leaving his body by the foot on the same side, which was also in contact with the switchboard. All his muscles being tetanised, he was thus held immovable. A second man caught hold of him to pull him away, but was also instantly knocked down by the current. It was not until a third man came to the rescue, and, recognising the danger of touching him with his bare hands, ran at him, jumping in the air at the same time, and knocked him away with his knee. Strange to say, the first man recovered, with no worse result than two bad burns on his shoulder and foot. Probably the fact of an arc being formed limited the amount of current passing to him, and this explains his escape in spite of the enormous voltage of the current.

Usually, after a severe electric shock, if the man has escaped instant death, he will be found semi-conscious, gasping, pulse thready and small, pupils dilated and sluggish or irresponsive to light. The skin is moist and cold, and the limbs flaccid. There may be signs of burning at the points of contact, and the respiration may have entirely failed, or be on the point of doing so. Artificial respiration should be at once commenced, and persisted in until regular breathing is re-established, and the usual remedies for shock administered; some brandy or sal-volatile, diluted with water, should be given by the mouth, and, if necessary, injections of ether hypodermically; while his hands and feet are chafed, hot bottles applied, and the legs raised and bandaged. There is always great fall of blood pressure, and it is this, due to arrest or enfeeblement of the action of the heart, that is the chief danger. The failure of respiration will also kill, of course; but this is more easily treated than is the syncope from the direct action of the electric shock upon the heart.

Hitherto, in this country, there has been practically no danger to the public from high tension currents, owing to the careful insulation underground of such cables, and their non-exposure before the current they carry is transformed into a lower and safer voltage. In America and on the Continent there are numerous long line transmissions of electric energy by bare wires carried on poles overground, the currents being at various pressures up to 50,000 or 60,000 volts. Necessarily, these bare wires must increase the public danger, owing to the liability of the poles being overturned, or other accidental contact with the wire by telephone wires, etc. The near future seems to foreshadow an increasing development of high tension alternating current electrification, by overhead trolly wires, of suburban railways, or even of longer lengths of main line, such as the New Haven Railway in America. The Berlin system of suburban railways is being electrified on these lines, as is the London and Brighton suburban service in this country. Countries like Switzerland and Sweden, with no coalfields, but practically unlimited water-power, are sure soon to electrify their railroads, and this will probably mean the transmission of electric power over long distances at high pressures. Thus, in the future, the number of high-pressure overhead wires is bound to multiply enormously, increasing especially the risks of the railwaymen, and, to a certain extent, of the public.

CHAPTER X

THE SINUSOIDAL CURRENT

THE sinusoidal current is a form of alternating current whose electromotive force regularly rises and falls in two equal and opposite cycles, the curve being sometimes known as a sine curve. We have already seen when dealing with the faradic current that the curve of the electromotive force of a faradic battery is an alternating current, though the waves are much stronger in one direction than in the other, and are also far less regular and more jerky. For several years previously to 1831 it had been recognised that there was a close association between electricity and magnetism, and it was known how to magnetise a piece of soft iron by passing an electric current around it, but it was reserved for Faraday in that year to demonstrate the solution of the converse problem—how to produce an electric current by means of the action of magnetism. If a coil of wire is wound on a bobbin and the two ends are connected to a galvanometer, and then a fixed bar magnet is quickly pushed inside the coil, the galvanometer will indicate the passage of a current. If the magnet is quickly withdrawn a similar current will be generated in the coil of wire, but running in the opposite direction, as indicated by the needle of the galvanometer turning the reverse way. The direction of the induced currents in any given case, and therefore of the electromotive forces giving rise to them, can be readily determined by the simple law first enunciated by Lenz, and known as "Lenz's law": "The direction of the induced currents is such as to set up a magnetic field which will tend to retard the change to which the induction is due."

Now, fixed magnets are too heavy in practice to move in and out of coils, or to rotate in front of coils for the production of these alternating currents on a large scale, and the next step in the development of alternating current machines was Clarke's magneto-electric machine in 1835. In this machine a heavy fixed steel magnet is used, and an armature consisting of two coils of fine wire with soft iron cores, and joined together at one end by a bar of soft iron, is rotated by means of a wheel and gearing in front of the poles of the fixed magnet. The coils are wound in series with a continuous wire, reversing the direction of the winding in the two coils, and the two ends of the wire are connected to spring contacts leading the currents developed in the coils to the terminals. These are alternating currents, and "medical magneto-electric" machines built on this principle are still frequently sold. The steel magnet is provided with a "keeper" or armature made of soft iron, and this is attached to a lever, by means of which the strength of the current can be graduated by altering the amount of contact permitted between the iron bar and the poles of the magnet. These machines have been completely replaced in medical treatment by faradic batteries driven by cells.

In the early Clarke's machines a commutator was arranged on the axle of the rotating armature, by means of which the alternating current became a pulsating unidirectional current, by altering the direction of the current of each half-phase. This current had very slight physiological effects, though it would decompose water, and had all the properties of a galvanic current. In order to produce a strong current and muscular contractions the following device was added to the machine (Fig. 15): The axle of the commutator is prolonged as a piece of ivory or other insulating material, and on it are prolonged two narrow strips from the halves of the commutator. Against these presses a spring which is so connected as to short-circuit the current from the commutator, so that as the commutator revolves, whenever the spring touches either of the two strips, no current passes to the terminals; and this will happen with every half-turn. The wires from the terminals leading to the patient are each led through two long coils before being attached to the handles, and the effect of this arrangement is that as the commutator revolves a current is thrown into the wires and coils in the patient's circuit; but by the action of the spring contact on the commutator this current is not maintained constantly, being broken with every half-turn of the commutator; and with each break of this battery current there is a sudden induced extra current produced in the coils leading to the handles, which is quite strong enough to produce muscular contractions and tetanus of muscles when the machine is worked sufficiently rapidly. The current from these magneto-electric machines is, therefore, comparable to the primary current from a faradic coil.

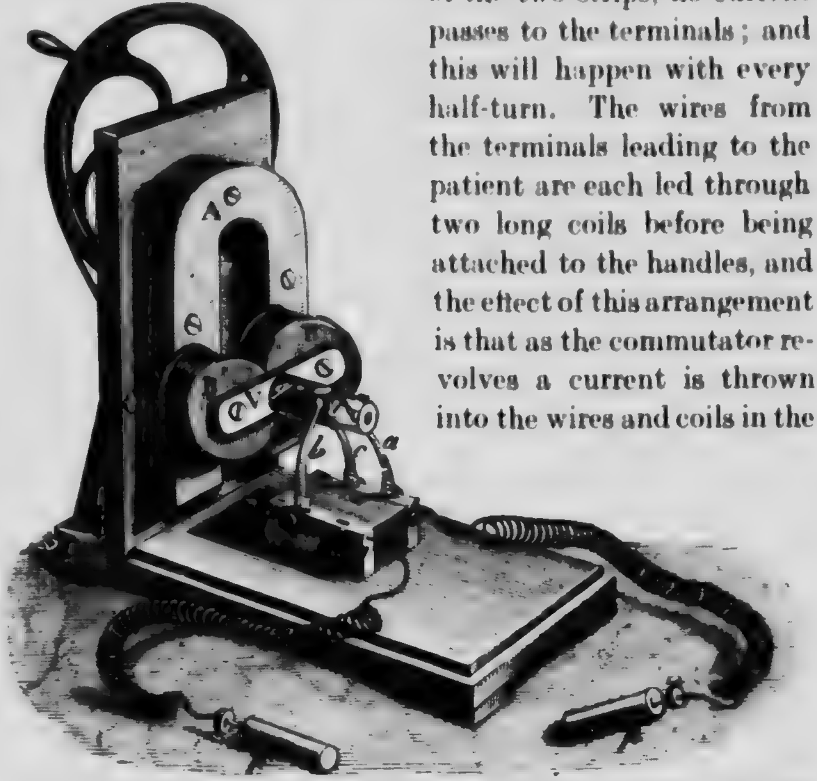


Fig. 15.—Clarke's magneto-electric machine, with commutator and coils.

The next step in the development of magneto-electric machines was to use electro-magnets instead of fixed steel magnets, and to rotate the moving parts by steam power, the machine now becoming a "dynamo."

A **dynamo** consists of heavy electro-magnets with two or more north and south pole pieces arranged alternately to form a more or less circular magnetic field, in which rotates an armature that is driven from some source of power such as a steam-engine or an electric motor coupled to it. The **armature** consists of a soft iron ring built up of a number of thin iron discs, insulated from each other in order to prevent the formation of eddy currents, which would overheat the armature. Around the iron ring is wound a coil of wire, and the rotation of the coils of wire through the lines of magnetic force generates induction currents in the coils. These currents are alternating currents, the change in sign of the voltage from + to − in any particular portion A of the coil taking place as A passes the middle line between the north and south poles of the magnet, or the "line of commutation," as it is called. This point corresponds to the zero line on the current curve. If B is a point on the armature exactly opposite A, then the current in B is exactly the reverse to that at A, both in direction and sign. Thus, for one whole rotation of the armature, the EMF of the current at any point passes through one complete cycle or period—one half positive, one half negative—for each pair of magnetic poles in the dynamo.

When a coil rotates with uniform velocity in a magnetic field, as between the poles of an electro-magnet, the current collected by the brushes is **sinusoidal**—*i.e.* the intensity of the current is proportional to the sine of the angle between the plane of the coil and the line of commutation. A similar current which does not change in direction is called an **undulating** current (*see* p. 283).

The periodicity of the current, or the number per second of complete cycles of positive and negative EMF depends on the number of revolutions per second of the armature. The voltage of the current depends on the speed with which the rotating coils cut the magnetic lines of force, thus varying with the speed of rotation and the diameter of the armature. The efficient intensity of the current may be measured by a milliampèremeter, such as Lord Kelvin's, consisting of an index attached to a movable coil rotating inside a fixed coil. The direction of the deviation is thus always the same whatever the direction of the current, since the phase of the current changes simultaneously in both coils. The maximum intensity of the current will bear the ratio to the efficient intensity of $\sqrt{2} : 1$; that is to say, the efficient intensity will be 70 per cent. of the maximum intensity.

In practice, sinusoidal currents are obtainable only where there is an electric lighting installation. The alternating currents supplied by some of these installations show very nearly a sine curve, and for medical purposes may be spoken of as sinusoidal currents. The number of complete cycles or periods per second depends on the type of machine employed in the power-house, and varies with different installations from a periodicity of about 40 to as high as 110 cycles per second when used for electric lighting; while for purposes of traction for railways as low a periodicity as 15 per second is now thought to be the best with single-phase alternating currents. As low a periodicity as 2 to 3 per second is recommended by R. Morton for the treatment of muscular wastings, and a specially shunt-wound dynamo has been devised by him and manufactured by Schall to run evenly at that slow speed.

To obtain graphic curves of currents of rapid periodicity an instrument called an oscillograph is used, such as Blondel's, in which the current passes through two small coils that oscillate on each side of the poles of a magnet. A mirror attached to a bar of soft iron oscillates between the two coils, and reflects a beam of light on to another mirror oscillating at right angles to the first, and thence on to a screen or photographic plate.

The curve in Fig. 16 shows graphically one complete cycle of such a curve. In it the time T is plotted horizontally, and the EMF of the current plotted vertically upwards (+) and downwards (–) from the centre line, which is also the zero line. The figures along O T are fractions

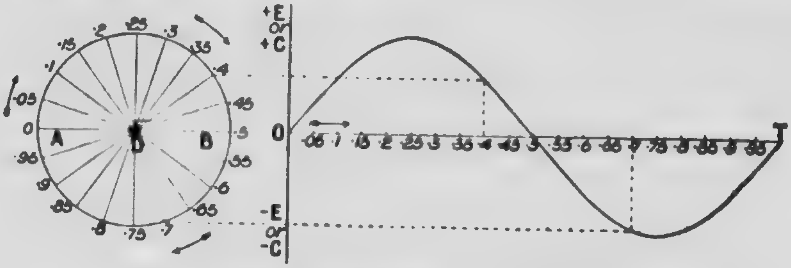


Fig. 16.—Simple construction for a "sine" curve.

of the periodic time which is represented by O T, the corresponding values of the function being obtained in the way shown by projection from the circle, the circumference of which has been divided into the same number of fractional parts as O T. The radius D O is to be regarded as revolving round D in a clockwise direction, so as to make a complete revolution in the time T. At each instant the distance of O above or below the datum line A D B will give the corresponding ordinate or vertical height of the sine curve.

An armature winding may be tapped by two wires at diametrically opposite points, and the wires led to two metal slip rings mounted on the axle and properly insulated from each other. The current collected by brushes rubbing on these slip rings will be a single-phase alternating current. If the armature windings are tapped at three equidistant points and wires similarly led to three slip rings on the axle, a three-phase current will be obtained from them. With four slip rings and four equidistant points of tapping the armature, either a two-phase or a four-phase current can be obtained according to the method employed of connecting the wires, and so on for other varieties of polyphase currents.

To obtain a continuous unidirectional current from a dynamo, the alternating currents which are induced in the armature must be collected by means of a **commutator**. The simplest form of commutator consists of a split metal tube fixed on the axle, the two halves being insulated from each other and connected by wires to two opposite points on the armature winding (Fig. 17). Brushes, usually made of carbon blocks, are fixed so as to rub against the two halves of the commutator at exactly opposite points. As the armature revolves, and the two halves of the commutator or split tube with it, although the currents

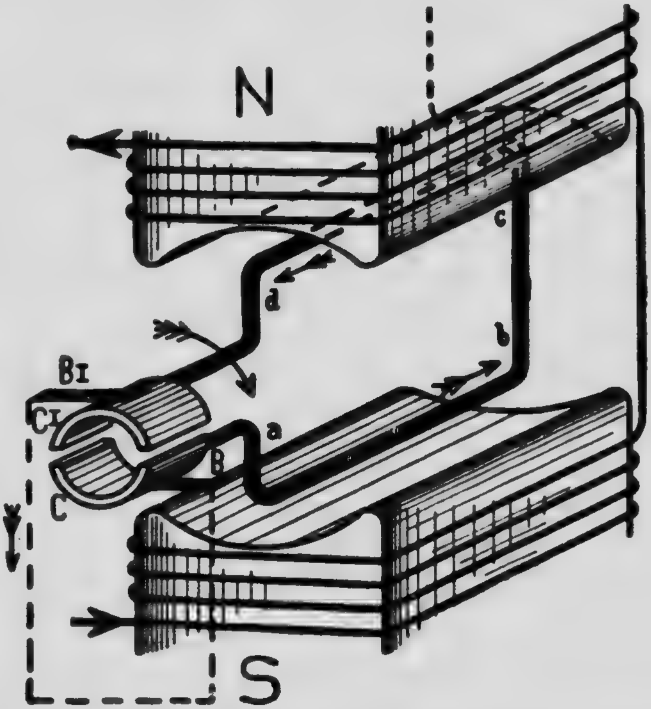


Fig. 17.—Diagram of a direct current (DC) dynamo, and commutator.

in the coils and in the two halves of the commutator are changing in direction with each half-revolution, yet the current picked up by the two brushes will necessarily be constant in direction, positive at one brush and negative at the other. The current curve will then have the form shown in Fig. 19, and is known as a pulsating unidirectional current (*see* p. 295). The commutators used on modern dynamos are much more complex, and instead of two halves of a split tube connected to two opposite points in the armature winding, the tube is split up into a large number of parts arranged in strips along the axle of the armature, all carefully insulated from each other. Each opposite pair of these strips is connected to two opposite points in the armature winding, and the resultant current collected at the brushes is a pulsating unidirectional current, with the same number of small waves of varying voltage as there are divisions of the armature winding and of the commutator (Fig. 18). Thus the constant current obtained from a dynamo is not, theoretically, a perfectly smooth current, but is a pulsating unidirectional current. Being unidirectional, it has, of course, electrolytic effects, and for practical purposes the dynamo constant current is nearly as smooth as a battery current.

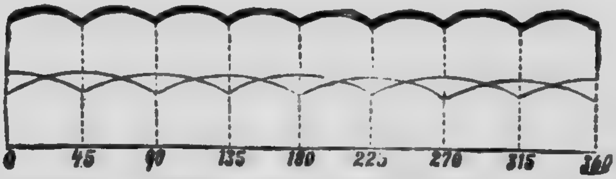


Fig. 18.—Diagram of EMF's of four pairs of coils in series ; a pulsating unidirectional current.

Such an armature as described, wound on a soft iron ring with a continuous coil of wire, which is divided into numerous sections, each of them connected to its corresponding part of the commutator, is known as a **Gramme Ring**. If the axle is prolonged on the opposite side to the commutator, and fitted with a pair of slip rings insulated from each other and connected to two opposite points of the armature winding, the machine can be used as a rotary converter. Used in this way, constant current from the main is fed to the commutator brushes and to the electro-magnets, thus driving the armature as a DC motor, and an alternating or sinusoidal current can be taken off the slip rings on the other side. Rheostats or graduated resistances must be used to reduce the voltage of the main current to that for which the armature windings are adapted. If single-phase alternating current is taken off the slip rings, its voltage will bear a proportionate ratio to that of the driving current as 1 : $\sqrt{2}$, or about 70 per cent. If a three-phase current is arranged for, its voltage between any two terminals will be as $\sqrt{3} : 2\sqrt{2}$, or 61 per cent. of the voltage of the exciting current. Further modifications can be applied to this machine, and by adding a commutator on the alternating current side the alternate phases of the current can be reversed, giving a pulsating unidirectional current (Fig. 19). Moreover, if such a machine is driven from a power source and run as a dynamo, it will supply constant current through the commutator brushes on one side and alternating current on the other.

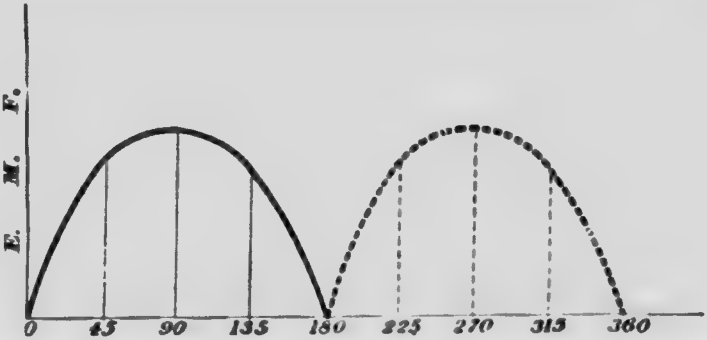


Fig. 19.—Connected alternate currents, or pulsating unidirectional current.

An **undulatory current** can be obtained from this machine by leading off a pair of wires from one of the commutator brushes on the DC side and from one of the slip rings on the alternating current side, thus forming a combination of constant and sinusoidal currents, or a sinusoidal constant current whose voltage varies rhythmically, but does not reverse its sign. This undulatory current has an electrolytic action like the constant current; but, in addition, it has the stimulant action on muscle of the variable current. Diagrammatically, its curve would be represented by a sine curve placed entirely above the base line.

A rotary converter is often spoken of as a **motor transformer,** and it is usually arranged to be driven by direct current and to give out alternating; but it may be built to be driven by alternating current, and then will give out constant current from the commutator brushes on the other side. A rotary converter is more compact than a coupled motor and dynamo, which is an electric motor driving another dynamo coupled to it on the same shaft. The motor and the dynamo may, however, be combined in the same machine, when it is known as a **motor generator.** This form has several advantages over the rotary converter. In the latter the transformed current circuit is in direct electric connection through the armature windings with the current from the main which drives the motor, and therefore there is a danger of shock through accidental contact with the earth current, through the patient or the operator touching a water tap or electric light switch. Therefore, when the machine is arranged to transform a direct into an alternating current, the current received by the brushes rubbing on the slip rings should be at once passed through a static transformer before being led off into the external circuit to cautery, lamp, or for treatment in the full bath. Most modern machines are provided with this safeguard, and if the static transformer is properly made, with the secondary winding thoroughly insulated from the primary, there is then no possible danger of any accidental shock from an earth current.

Another advantage which the coupled motor and dynamo, or motor generator, has over a rotary converter is that with the latter the voltage and periodicity of the alternating current is fixed, depending upon the voltage and speed of revolution of the DC motor, whereas with the former type of machine the generator half of the machine can be built to produce any required voltage or periodicity of alternating current.

Direct current motors may be "series wound" or "shunt wound." In the former the field magnets are excited by the same current in series with that which flows into the armature coils; in a shunt-wound motor the field magnets are excited through a side circuit or shunt. The current should always be turned on gradually, using resistances, or the armature may become overheated. Heavy motors for traction purposes are always series-wound, but all motors for medical purposes should be shunt-wound, as this arrangement ensures a non-variable supply of current to the field magnets, although the load on the motor may be varying frequently and suddenly. Moreover, the motor could not be run slowly and evenly unless shunt-wound.

A continuous current dynamo is reversible—that is to say, if the direct current at a suitable voltage is fed to the commutator brushes and field magnets, the armature will revolve and run as a motor.

Alternating current motors.—On the other hand, such a dynamo will not run in the same way if fed with alternating current through slip rings, for two main reasons. Firstly, the alternating current will not excite the field magnets; and even if these are separately excited by a continuous current from another motor, the machine will not start by itself, but will require to be speeded up until the frequency of the induced alternating currents in the armature coils gets into step with the periodicity of the driving alternating current. Once started, the machine will continue running at that invariable speed, unless overloaded, when it will drop out of step and stop suddenly. These are known as synchronous motors. Alternating current motors must be built specially for the voltage and periodicity of the driving current, and should the periodicity of the main current fluctuate, as it is liable to do in some badly supplied districts, the motor will be thrown out of step, and will stop at once. Such alternating current motors are, therefore, on the whole much less satisfactory than DC motors, though recent developments have produced very satisfactory single-phase alternating current motors for heavy traction purposes, using a current with a low periodicity of 15 cycles per second. An alternating current motor, even of the most recent and efficient type, weighs considerably heavier than a DC motor, and is about 20 per cent. less efficient.

High tension alternating current.—The alternating currents manufactured for electric lighting or power purposes are usually made by machines giving a very high voltage, in order to save the prime cost of copper in the transmission circuit. By this is meant that with currents of low voltage it will be necessary to send a very large ampèrage along the wires in order to develop the same power as in a case where the voltage is high and the ampèrage correspondingly low. It is to be remembered that the power expressed in watts is the number of ampères of current multiplied by the voltage. Now, 746 watts is one **electrical horse-power,** and for a machine of low voltage to develop the same electrical horse-power as one of high voltage it must produce a correspondingly larger number of ampères of current. A copper cable will carry 1,000 ampères of current per square inch of its cross section, and no more, without danger of the cable heating, irrespectively of the voltage of the current, and it is, therefore, clear that the higher the voltage at which the current can be delivered to the copper wire cables, the greater is the total amount of electric energy which those cables will carry. Now, with copper costing, as it did in February, 1907, in the neighbourhood of £100 per ton, the necessity of saving copper in the transmission circuit is obvious, especially if the district over which the electric energy has to be delivered is a large and scattered one.

It is easy to build alternating current dynamos to produce the current at high voltage, which can be raised further by step-up transformers for delivery to the transmission line, and as high a voltage as 60,000 is used at Niagara in America, where the energy of the Falls is used to produce current for power and lighting purposes over a radius exceeding one hundred miles. In Switzerland, Zurich is now supplied with three-phase alternating current, giving 22,000 horse-power at a pressure of 45,000 volts, generated by water power at Thusis, eighty-five miles distant. In this country 11,000 is the highest voltage used, for the London Underground Electric Railways, and 10,000 by the London Electric Supply Co., at Deptford. Most of the alternating current street mains are at a pressure of 1,000 volts, each house supplied with it having a static transformer fixed in some safe position in the basement, in order to transform the current down to 200 or 100 volts, before it is led into the house. The 1,000 volt terminals of the street wires and the transformer should always be carefully enclosed in stout wire cages, in order to prevent interference by unauthorised persons, as an accidental shock at that high voltage would in all probability be immediately fatal.

For the underground electric railways the high-pressure alternating current is used to drive motor-generators at a few sub-stations, in which the current is transformed into a direct current at about 550 volts, at which pressure it is supplied to the locomotive from a third rail. Efficient alternating current motors can, however, now be built and the question as to which is the more suitable type for traction purposes, alternating or direct current, is still being keenly debated by electrical engineers. The latest development in this direction is an enormously powerful electric locomotive of 4,000 horse-power, built by the Westinghouse Company in America for the Pennsylvania Railway. This engine, weighing 125 tons, receives a single-phase alternating current at 11,000 volts from an overhead trolly wire, the current being transformed by static transformers on the engine down to 550 volts, of course alternating at the same periodicity of 15 cycles per second. The speed is varied by changing the voltage delivered to the motors from the transformer, no rheostat being used in the control, a speed of 75 miles per hour being easily obtained under load.

High voltage direct current.—The great difficulty in building dynamos to produce direct current at a high voltage is on account of the excessive sparking at the commutators, which are thus soon burnt out. On account of these commutator difficulties, it has usually been the practice to limit the voltage of DC dynamos to a maximum of 650 volts. A laboratory dynamo has, however, been built to produce direct current at 11,000 volts. In commercial practice the voltage of the direct current may be raised for long line transmission of power by the Thury system of coupling a number of dynamos in series. Lausanne, in Switzerland, is thus supplied by a direct current of 105 ampères, at a maximum pressure of 23,000 volts, which is generated thirty-five miles away at St. Maurice by 5,000 horse-power turbines, driven by water power from the river Rhone. In the power station are ten dynamos of 2,300 volts each, all of which may be coupled in series if required. To render this safe, each dynamo is bedded on porcelain insulators, sunk in an asphalt concrete foundation. The copper cable which carries the 2,415 kilowatts of electric energy is only two-thirds of an inch in thickness. In the Moutiers-Lyon plant, 6,300 horse-power is transmitted by the Thury system more than one hundred miles, at a pressure exceeding 50,000 volts.

It is, however, found that the loss by leakage is less with alternating than with direct current at high pressures, and the ease of transforming the alternating current to any required voltage, especially with oil-insulated water-cooled static transformers, cannot be rivalled by even the Thury system of direct current high-pressure transmission. The alternating current is, therefore, likely to entirely replace the direct current in large power-houses where the output of current energy is heavy, and especially if it has to be transmitted over a long distance. The leakage is proportionately greater with high than with low pressure currents; but, as a rule, this is more than compensated by the saving in prime cost of copper cables. On the other hand, the danger to life from accidental contact with the high tension currents is much greater than with the low tension current, and therefore circuits employing the high tension alternating current require to be especially protected.

To transform the voltage of a direct current a motor generator must be used; that is to say, the main direct current is used to drive a DC (direct current) motor, which is wound for the main voltage. This motor drives another dynamo wound to produce the required voltage of direct current. The motor and dynamo are built on the same bedplate, and the apparatus is sometimes known as a **rotary transformer**. Alternating currents are much easier to deal with in changing the voltage, a static transformer with no moving parts being all that is required. This, in its essentials, resembles the primary and secondary windings of a faradic coil, the main current running through one coil, and an induced current is produced in the surrounding coil. The voltage of the induced current will vary with the proportionate number of turns of wire in the primary and secondary coils, and to reduce the voltage of the street main at 1,000 volts to a voltage safe to use in houses, such as 100 or 200 volts, the induced circuit must have a comparatively few turns of thick wire, while the primary main circuit consists of a large number of turns of thinner wire. On the other hand, in a step-up transformer, as is used in generating high frequency currents from the alternating electric light current, the inducing circuit must consist of a large number of turns of thin wire. The voltage of the current used in any house will be indicated on the incandescent lamps used in it, though the lamps will give no indication as to whether the alternating or the direct current is supplied to the house.

CHAPTER XI

MEDICAL APPLICATIONS OF THE SINUSOIDAL CURRENT

If the electric supply is by alternating current, a simple form of **sledge transformer**, costing about 30s., will suffice to reduce the voltage for all methods of applying the single-phase current to patients. Such a transformer closely resembles the sledge coil used for the faradic current, but the iron core of the primary must be larger, and there is no interruptor. The thickness of the wire used in the primary and secondary coils, and the number of turns in the two coils, will depend on the voltage of the current supplied to the house and the voltage that it is desired to obtain from the secondary. With a 200-volt main current, the primary windings should be of about the same thickness, but with many more turns than the secondary, as the voltage of the current must be reduced; but if an accumulator of 12 or 20 volts were being used to drive a motor to produce alternating current, the secondary winding of the sledge coil would have to be made with much finer wire and with a far greater number of turns than the primary.

The same type of volt-selector that is used for the direct current will also serve with the alternating current (p. 26). It is also known as a shunt rheostat, since the patient's circuit and the coil circuit are alternative paths for the current. As soon as the current is turned on the lamp glows a dull red, and current is being continually used, whether the shunt circuit to the patient is used or not. Since the current is thus continually passing through the wire of the rheostat, this is gradually heated owing to the resistance offered by the wire; and if the hand is placed upon the coil wound round the slate bed the coil will feel hot after it has been in use for a few minutes. It never becomes dangerously hot, however, or hot enough to burn the insulation of the neighbouring coils. If the metal bar is kept well polished, and the surface of the coil bright, the metal spring will slide smoothly on the coil, giving a regular and smooth increase of voltage and current without any sudden shocks to the patient.

This form of volt-selector will do equally well for the direct or alternating current; but if the alternating current is required for use in the electric bath, then a modified form of apparatus will be necessary, since that just described will not protect the patient from the earth current due to leakage. Moreover, even if not immersed in a bath—only one arm, for example, being treated in an insulated arm bath—were the patient to touch a water or gas tap or electric switch with his other hand, he would be liable to a severe shock at the same pressure as the full voltage used in the house. For that reason, the precaution is taken of inserting a new small transformer circuit on the volt-selector apparatus (Fig. 8, p. 33), consisting of two coils of wire, primary and secondary, one placed over the other, but having no contact with each other, just like the primary and secondary coils of a faradic battery. The wires from the house main are connected with the primary coil, while the secondary coil is connected to the rheostat or volt selector. This latter circuit is, therefore, completely insulated from the main current, as the patient's circuit is supplied only by the current which is induced in the secondary coil. Its method of induction is similar to that of the larger stationary transformer in the basement of the house, only of simpler design; it closely resembles a faradic primary and secondary coil, but without the interrupting hammer of the latter. No interruptor is necessary, because the exciting current is already alternating; whereas in the faradic apparatus the exciting current in the primary is a constant current, and therefore it must be rapidly interrupted in order to induce an interrupted current in the secondary. With this modified form of rheostat there is absolutely no danger of any accidental shock from leakage of earth current, but the apparatus can only be used for alternating current.

In districts which are supplied by the direct and not alternating current, the direct current can be made to yield the alternating type by means of a motor transformer. The direct current is used to drive a DC motor, wound for the particular voltage of the circuit; and the armature of the motor is tapped at two exactly opposite points and the current led to a pair of slip rings insulated from each other on the axle of the motor. Thence the current can be collected by means of brushes rubbing on the rings and led to terminal binding screws. This current is an alternating current, and its voltage compares with that of the direct current driving the motor as $1 : \sqrt{2}$. That is to say, if the voltage of the direct main current driving the motor is 240 volts, then the resultant alternating current is produced at a pressure of about 170 volts, roughly about five-sevenths, or 70 per cent., of the voltage of the main driving current. This current is not, however, perfectly safe to use for all purposes, because it is more or less in contact through the motor with the main current, and there is, therefore, a danger of shock from an earth current. It can, however, be made absolutely safe by passing the alternating current obtained from the machine through a small transformer similar to that described above for using the alternating main current in the electric bath. The best modern machines supplied by medical electricians now always include such a transformer, and the current that is used for application to patients, or for cautery and light, being taken from the induced current in the secondary winding of the transformer, is absolutely safe, with no possibility of shock from an earth current, and the patient or operator can touch with impunity an electric switch or water tap while using this alternating current.

The simple alternating current just described is sometimes spoken of as single-phase, the positive and negative phases of its electromotive force succeeding each other with perfect regularity, so that if the curve of its EMF is plotted out graphically it approximates a true sine curve (p. 280). Owing to the rapid oscillations of its EMF the action of the current on neuro-muscular tissue resembles that of faradism, the muscle being tetanised. Moreover, since the positive and negative values of the current rapidly succeed one another, from 40 to 110 times per second, the current has no electrolytic action. With special machines to increase the periodicity of the current, it has been found that muscular excitation increases with the frequency up to 2,000 or 3,000 alternations per second; it then diminishes and disappears entirely above 10,000 alternations per second. At this point the phenomena of high frequency currents begin to appear. Sinusoidal currents at frequencies of 20 to 150 per second produce good motor results, especially upon non-striated muscle. To obtain alternating currents with lower frequencies than 40 per second, a motor generator must be used which is wound to produce the slow speed of alternation required (p. 188).

If the sinusoidal current is obtained from the alternating current mains, its periodicity, or number of complete cycles of EMF per second, will be fixed, depending on the frequency of the alternations in the generators at the power-house. These usually vary in different districts from 40 to 110 per second, but the periodicity ought not to vary in the particular installation. Lower frequencies than 40 per second are unsuitable for electric lighting circuits, that speed being the least that will maintain a steady glow in an incandescent lamp.

If the sinusoidal current is obtained from a motor transformer, driven by the direct main current, the periodicity of the transformed current will depend on the speed of revolution of the motor, and its voltage will be about three-fifths of the voltage of the driving current.

If an alternating current is passed through a coil of wire around a soft iron core, it has a certain magnetic action on the iron, and it is this property which is made use of in an instrument called the "Neuron," which is a large alternating current electro-magnet (p. 307).

This property of the current can be tested by passing the current from a lamp resistance through the primary coil and interrupting hammer circuit of an ordinary cell-driven faradic battery. If the hammer is well hung and the spring tension is correctly adjusted, it will be found that the interrupting hammer begins to vibrate gently, and this test is sometimes used by instrument makers for a correctly adjusted faradic apparatus.

Modified forms of sinusoidal currents: pulsating unidirectional current.—By means of a commutator fixed on the axle of the motor transformer, it is possible to alter the form of the sinusoidal current so that instead of obtaining negative waves of EMF immediately following and equal to the positive waves, the current consists of a succession of positive waves. It is, so to speak, as if the negative waves of the sine curve had been turned over and laid down again on the upper side of the base line (Fig. 19, p. 283).

A somewhat similar effect can be produced with the alternating current from the main by passing it through an electrolytic rectifier of aluminium cells, called a **Nodon valve.** These cells have the property of offering a very high resistance to the waves of EMF in one direction, but offer practically no resistance to the waves of opposite sign. Each cell will thus block the waves in one direction up to a pressure of 22 volts, and, therefore, to block out all the waves in one direction for a current of 100 volts, it will be necessary to use five of such cells in series, and twelve cells for a current of 240 volts. Using this arrangement, a pulsating unidirectional current is obtained, somewhat similar to that just described, but with only half the number of waves, the alternate waves being blocked. This Nodon valve arrangement is made use of sometimes in X-ray work for employing the alternating current main for working the X-ray coil and its interruptor, for it has the effect of producing a current constant in direction though pulsating, the speed of the interruptions being one half the periodicity of the particular alternating current used. A good form of aluminium electrolytic rectifier has a large passive electrode of lead, and a smaller active electrode of an alloy of zinc and aluminium, in a saturated solution of ammonium phosphate. Aluminium has the property of offering a great resistance to the passage of a current when it is the anode, so that a current of less than 22 volts cannot pass at all; when the aluminium is the kathode no resistance is offered to the passage of the current. This action is due to a polarising effect of the current, so that a thin film of aluminium oxide is formed upon the anode. This electrolytic rectifier gets warm with prolonged working, and the valve effect falls off when the temperature exceeds 40° C.

An economical way of using the alternating main current for X-ray coils is to charge accumulators through a Nodon valve, and work the coil and its interruptor off the accumulators.

Polyphase currents.—We have already spoken of the single-phase alternating current, which is the form usually supplied on main alternating current circuits. This is obtained by tapping the current induced in the rotating armature at two diametrically opposite points, and leading the current to a pair of insulated rings on the axle, whence collecting brushes deliver it to the external circuit. If, however, the windings of the armature be arranged in three groups at equal distances, and one end of the wire winding of each is led on to a collecting ring on the axle, while the other ends of the three groups are connected together, we shall then obtain what is called a "three-phase" current (Fig. 20). Three separate waves are generated, each of which is exactly like a single-phase wave, alternating positive and negative, so that with three slip rings, A, B, C, from which are led off three wires attached to three electrodes, there will be a flow of current between A and B, between B and C, and also between C and A. Similarly a two-, four-, or five-phase current might be produced by dividing the winding of the armature into four or five equal parts, leading one end on to separate insulated slip rings on the axle, and joining together the other ends.

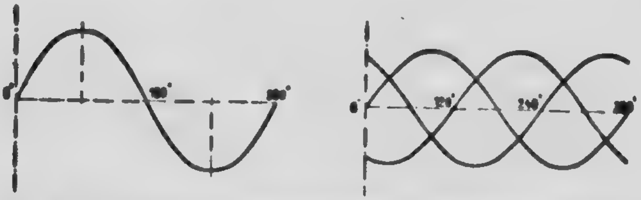


Fig. 20.—Diagram of single-phase and three-phase currents.

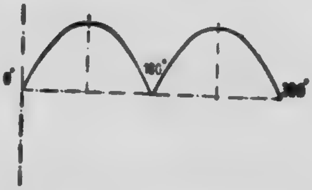


Fig 20a.—Diagram of pulsating unidirectional current.

A two-phase current is produced by arranging the windings of the armature in quadrature, four slip rings and four wires being necessary. The maximum of the positive and negative values of the second phase occur precisely at the moment that the curve of the first phase crosses the zero line; that is to say, the second phase is exactly one-quarter of a whole cycle later than the first (Fig. 21). The voltage ratio of a three-phase current to that of the direct current driving the converter will be as

$\sqrt{3} : 2\sqrt{2}$, or 61 per cent. A two-phase current will be 70 per cent., and a four-phase current 50 per cent. of the driving current voltage.

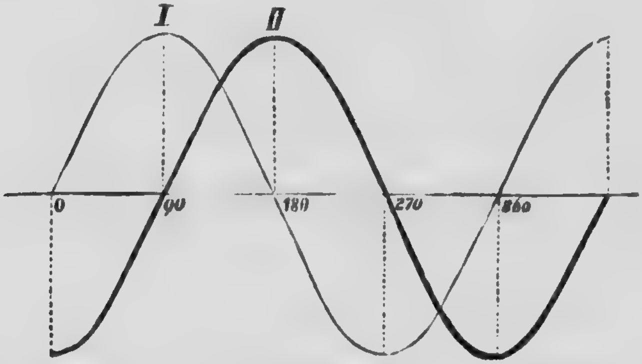


Fig. 21.—Alternate currents in quadrature, or "two-phase" current.

Three-phase sinusoidal currents are sometimes employed in medicine, and they form a very smooth and easy form of current to bear. The method of obtaining them is to drive a DC motor and to tap the armature at three equidistant points, leading the currents to three

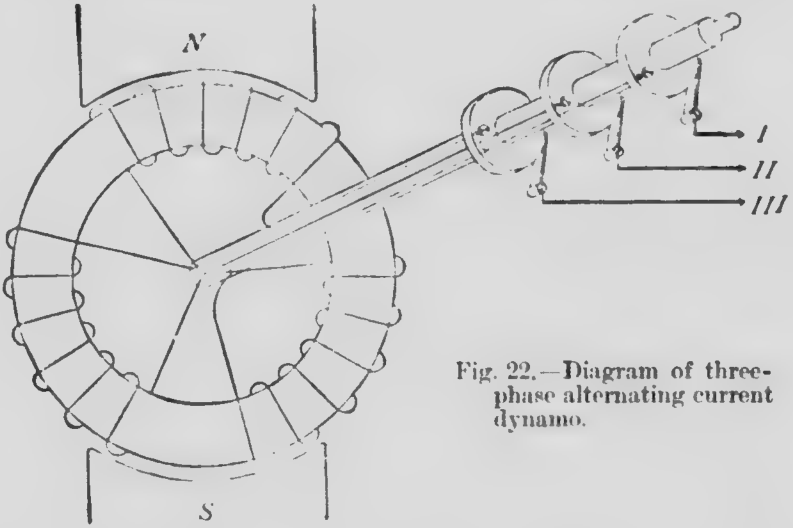


Fig. 22.—Diagram of three-phase alternating current dynamo.

insulated slip-rings on the axle (Fig. 22). The currents taken off from these rings by means of collecting brushes are led through three primary coils of a sledge transformer, the secondary coils which slide over the primaries being usually fixed together so that one movement pushes them all forwards or backwards (Fig. 23). The induced currents developed in these secondary coils are led by means of three wires and electrodes to the patient or electric bath. Owing to the complete insulation of the patient from the main circuit by means of the sledge transformer, there is absolutely no risk of any accidental shock from an earth current.

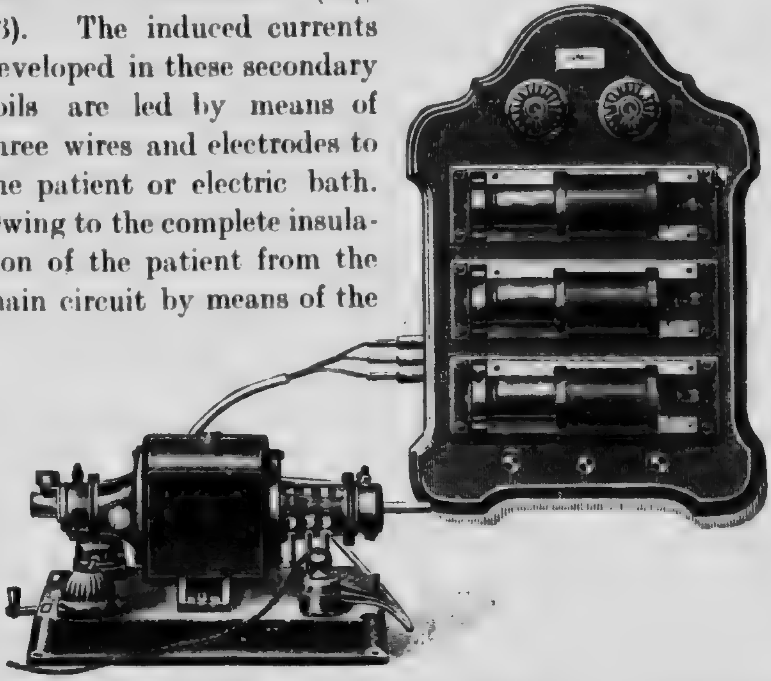


Fig. 23.—Motor transformer, with three sledge coils, to utilise direct main current, producing single-phase or three-phase sinusoidal currents.

These three-phase currents are useful in the treatment of **gastric atony and dilatation,** one pole being passed into the stomach by means of a special intragastric electrode, as described under "Faradic Treatment." If this instrument is not available a good substitute may be made by passing a flexible stomach-tube into the stomach, and after pouring a little warm water down the tube pass a medium stiff copper wire down inside the stomach-tube after well buttering the wire to make it slip down easily. The necessary length to which the copper wire is to be passed must be first marked upon it by measuring it against the stomach-tube, and it should be passed just a sufficient length for its lower end to rest against the lower orifice of the stomach-tube. Three-phase currents may also be similarly made use of for intrarectal treatment for **constipation**, or for the full bath treatment. Since atony of the lower bowel and constipation so frequently accompany gastric atony and dilatation of the stomach, a good arrangement of the three electrodes when using three-phase currents in the treatment of this condition is for one electrode to be passed into the stomach and one into the rectum, while the third should be a pad electrode applied to the epigastrium.

With a machine built for supplying three-phase currents it is not always necessary to use all three electrodes, as if only two are used the patient will then receive a single-phase current.

We have already mentioned that a pulsating unidirectional current may be obtained from such a machine by the comparatively inexpensive device of fixing a commutator upon the axle, so that the same machine may be made use of for three-phase, single-phase, or pulsating unidirectional current. It is also possible to fit the axle of these machines with the Leduc transformer for the direct current, to convert it into a rapidly interrupted or a rapidly reversed galvanic current. Moreover, the machine may be fitted with a lamp resistance, volt selector, and galvanometer for the application of direct current, and a separate volt selector for the use of the transformed alternating current for cautery and lamp. The motor may also be used to work a dentist's or surgeon's drill, or a flexible apparatus for applying vibratory massage.

To recapitulate: a motor transformer worked by the direct main current can be arranged to supply (1) direct current for electro-therapeutic application, (2) single- or three-phase sinusoidal currents for electro-therapeutic purposes, (3) alternating current for cautery, (4) alternating current for surgical lamps, (5) pulsating unidirectional current for electro-therapeutic purposes, (6) Leduc currents (interrupted or rapidly reversed galvanism for application to patients), (7) vibratory massage, (8) motor power to work a dental or surgical drill, trephine, etc. These machines are made remarkably compact, and will cost from £20 to £35, according to their size and equipment.

Sinusoidal current is an extremely useful form of current for **bath treatment,** either for local arm- or leg-baths, for the four-cell Schnée bath, or for a full electric bath. As previously said, in its general effects it resembles faradism in its tetanising effect on muscle, but the current is much less painful than faradism, owing to its smoothness and regularity of alternation. Faradism, moreover, is not so truly an alternating current, the break currents being so much more powerful than the currents developed at make, that the faradic current is, to all intents and purposes, a unidirectional current. Sinusoidal current electric baths are a most excellent method of treating cases of spastic paralysis, whether hemiplegic or paraplegic; it is also useful for tabes dorsalis, peripheral neuritis, and muscular atrophies. In spastic cases, as in the late rigidity of hemiplegia and in spastic paraplegia from myelitis, disseminated sclerosis, etc., the current in the majority of cases appears to diminish the rigidity, so that the fingers and wrist or the ankle can be moved more easily, and the patients feel better and stronger.

In the treatment of the commencing late rigidity of **hemiplegia,** an arm bath and a foot bath should be used, the arm bath being arranged by the side of a chair in which the patient sits, so that the whole forearm can be placed comfortably in it, the water covering the elbow. A foot bath is similarly placed for the foot of the paralysed side. If the Schnée bath is available, the arm-bath and foot-bath of one side only are to be used, one electrode dipping into the water of each bath. The current should be applied daily for about twenty minutes by means of the shunt rheostat or volt selector, using a pressure of about 10 volts. The strength of current should be just sufficient to tetanise weakly the muscles of the forearm, and, with the forearm immersed in water, the supinator longus will be seen to stand out in contraction as the pressure of the current approaches 10 volts. Massage to the paralysed arm and leg should be given daily also if possible.

Spastic paraplegia, whether due to disseminated sclerosis, a previous attack of acute transverse myelitis, or to chronic combined or lateral sclerosis, may often be advantageously treated by means of alternating current baths, each foot placed in a foot bath with warm water to cover it up to the ankle. The effect of the current is to diminish the spasticity, and thus the limb appears stronger and more lifelike to the patient. Each volt selector is usually provided with a graduated scale placed along it, and an indicator attached to the sliding spring contact to mark the point reached on the scale. These scales are purely arbitrary in their divisions; but when the sliding spring contact is pushed as far to the left as possible, the maximum voltage obtainable will be about 70 per cent. of the main current pressure supplied to the rheostat. In practice, the point on the scale at which the voltage is usually sufficient for one patient with good water contact will become familiar to the operator through constantly using the same rheostat. Patients who are paraplegic, however, or who are anæsthetic, usually require a greater voltage and a correspondingly higher number on the scale for their treatment.

Progressive muscular atrophy, due to chronic anterior poliomyelitis, may be treated with sinusoidal current baths, either with the four-cell or the full hydro-electric bath; but, as a rule, it will be better to treat these cases with galvanism either in the full electric bath or in arm or foot baths, using the direct or constant current, slowly reversed about twice a second by means of a mechanical reverser, such as the metronome previously described, fitted with a small Pohl's commutator (p. 143.)

Muscular dystrophies, or myopathies, may be treated with sinusoidal current arm- and leg-baths, and I have treated a case of the Landouzy-Dejerine type at St. Mary's Hospital regularly twice a week for about six years, during which period the patient is confident the weakness did not get any worse, though for the previous seven years he had gradually become extremely wasted and weak.

The muscular dystrophies are usually divided into four groups for clinical classification: (1) Pseudo-hypertrophic, or Duchenne's paralysis; (2) Erb's juvenile progressive muscular atrophy; (3) Landouzy-Dejerine type, or facio-scapulo-humeral; and (4) peroneal type, or type of Charcot-Marie-Tooth.

In all the muscular dystrophies the electrical reactions will be diminished in proportion to the degree of muscular wasting. The reactions both to faradism and to galvanism will be sluggish, but there is nothing approaching the reaction of degeneration.

The **pseudo-hypertrophic type** nearly always commences in childhood, and is almost limited to the male sex. It is markedly hereditary, and is transmitted through the female line, though the females themselves usually escape. The males rarely live long enough or retain sufficient strength for marriage. The muscles that are usually hypertrophied are the gluteus, gastrocnemius, deltoid and infraspinatus, while the first muscles to atrophy are usually the upper arm and thigh muscles, and the muscles bounding the axilla and shoulder girdle, the lower pectoral, latissimus, the whole of the trapezius, serratus magnus, and later the erector spinæ. For the first few years there may be no atrophy of the forearm or leg muscles, though these, too, may suffer later. Owing to the weakness of the thigh muscles, including the extensors of the knee, walking, especially upstairs, is difficult, and so too is rising from the ground. Deformities ultimately cripple the patient, owing to contracture of other muscles, causing talipes of different kinds, scoliosis, etc. The muscular atrophy is usually remarkably symmetrical, and that point, together with the absence of fibrillary tremors, its heredity and distribution in several members of the same family, and the fact that the distribution of the muscular atrophy does not correspond to spinal segments, all combine in differentiating the disease from a chronic spinal atrophy.

Erb's juvenile form somewhat resembles the pseudo-hypertrophic in the distribution of the atrophy and its slow progress ; but differs from it in affecting both sexes about equally, in commencing later, about the age of puberty, and in the absence of any pseudo-hypertrophy. Like the pseudo-hypertrophic, it tends to run in families.

Landouzy-Dejerine type may be compared to the Erb's juvenile form, with the addition of symmetrical facial atrophy. This myopathic facies is peculiar and easily recognised, the atrophy of the frontalis giving a very smooth appearance to the forehead ; and there is additional atrophy of the sphincter muscles of the eyes and lips, the patient being unable to close the eyes or purse up the lips, while the eyes usually appear very prominent and the lips have a peculiar pouting appearance. The facial diplegia in this type of muscular dystrophy usually dates from birth, and the mother may notice that the infant is unable to suck or to close the eyes properly. In early childhood, and up to the age of nine or ten, there may be no further atrophy of any other muscles noticeable, and the case may be misunderstood unless it is remembered that the facial atrophy of this group of the myopathies is distinctive, and may date from infancy.

The peroneal type of Charcot-Marie-Tooth may be divided into two forms—the progressive neuritic and the myopathic. The latter, like the other myopathies, is strikingly hereditary, and probably affects several members of the same generation. Its distinctive character is the primary wasting of the muscles below the knee, the calf and anterior tibial and intrinsic foot muscles all becoming atrophied. The atrophy next affects the lower portion of the thigh muscles, the legs appearing peg-top shaped; the intrinsic hand muscles are next involved—muscles which rarely show much wasting in the other myopathies and then only late in the disease, when the upper arm and shoulder girdle muscles are extremely wasted.

The **progressive neuritic** form is not really a myopathy or muscular dystrophy at all, but may resemble the form just described in its muscular distribution. The nerves are sometimes much enlarged and prominent, such as the external popliteal and ulnar; and there is often extensive anæsthesia, which may be dissociated as in syringomyelia; or it may be reversed, with loss of tactile sense and preservation of the sense of pain and temperature. In some of these cases the pupils may be of the Argyll-Robertson type, with loss of the reaction to light, and autopsies upon them have shown extensive degeneration in the posterior columns, in addition to the hypertrophic neuritis.

Myotonia congenita, or Thomsen's disease, is an hereditary condition of muscular rigidity affecting especially the limb muscles, in which the rigidity appears while the muscles are at rest, thus hampering movements at their commencement, though as the movements are continued the rigidity wears off for the time, as long as the motion is continued. Electrical treatment appears to be of no service in these cases.

Amyotonia, or myatonia congenita, is a curious form of lack of muscular development in young children, in which there is no particular group affected; but all the muscles of the lower extremities, or, in some cases, the trunk and upper limb muscles also, are apparently equally wasted and atonic, though really they are undeveloped. They are extremely flaccid and all the joint movements are limp, so that the feet and legs can be placed in practically any position without any resistance being offered by tonic muscular action. The knee-jerks are usually absent. There is little or no voluntary power over these muscles, and the children usually lie or sit huddled up, and are unable to stand or walk, but may be able to crawl about the floor in a squatting, frog-like position. The condition is sometimes congenital, and in other cases the child may appear to be normal for the first year or two, and the condition may then develop after some slight illness. The muscles react very slightly to faradism, and these children appear to tolerate surprisingly strong currents without any apparent pain. The prognosis is usually good, though progress is slow. The diseases for which amyotonia is likely to be mistaken are rickets, infantile paralysis, and myopathy. Persistent massage and treatment with faradic currents should be employed.

The **Werdnig-Hoffmann** type of spinal atrophy is a chronic progressive muscular atrophy, due to a chronic anterior poliomyelitis, in quite young children, even infants under a year old having suffered from it. In older children it may affect the facial and bulbar muscles, and it is always fatal in from one to four or five years. Probably the hydro-electric full galvanic bath daily would be the best form of electrical treatment for this rare disease.

Periodic paralysis.—This is a rare form of muscular paralysis affecting all the muscles of the limbs and trunk. It usually runs in families, and the attacks recur at intervals throughout life, commencing in early childhood.

Every now and then—it may be once a week, or only every few months—the patient, male or female, notices a rapidly progressive languor and heaviness of the limbs, sometimes accompanied at the commencement by slight pins-and-needles sensation. The limbs and trunk muscles become completely paralysed in a few hours, remaining in that condition for several hours to a day, when the power gradually returns again. At the same time, respiration is slightly hurried and difficult, though the diaphragm is never paralysed. Speech and the eye movements are not lost, nor is there sphincter paralysis, nor loss of sensation of any kind. Some dilatation of the heart has been noticed in several cases.

A very curious point in this form of paralysis, which has never been explained, is the loss of electrical irritability in all the paralysed muscles, both to faradism and to galvanism, though the electrical reactions return with the voluntary power. This condition, therefore, differs strikingly from myasthenia gravis, in which, after the muscle has been exhausted to voluntary power, it will still contract to faradism, and after it has been further exhausted to faradism it will still contract normally to galvanism. Moreover, muscles paralysed by curari will still react to electrical stimuli, and for these reasons it is thought that the lesion causing the temporary paralysis cannot be in the nerve fibres or any other part of the lower neurone such as the spinal ganglion cell or the end-plate in the muscle; but that there is some toxic condition in the muscle substance itself which is absorbed and passes off with time.

Neuralgia.—An apparatus which has been called the "Neuron" has been devised for the treatment of neuralgia and neuralgic headache. It consists of an alternating current electro-magnet, which is excited either by the alternating current from the main, or, if the main supply is direct current, by means of a sinusoidal current from a motor transformer driven from the main. This instrument certainly has a powerful magnetic effect upon iron and steel, and if a bunch of keys is held close to the pole some of the keys will be powerfully attracted, and others repelled. If the forehead is held against the pole a curious sensation is felt, rather unpleasant and productive of headache, and slight flashes of light may be noticed. These effects are probably produced by means of alternating currents induced in the tissues when the head is held close to the magnetic field. The magnetic field of an electro-magnet driven by means of a constant current is not rapidly varying, but steady, and therefore no currents will be induced in a body at rest in its neighbourhood; in fact, the majority of people are unable to perceive any sensation on contact or close to the poles of even very powerful DC electro-magnets.

Electro-magnetism.—Although, as seen in the last paragraph, electro-magnets are of no service for therapeutic purposes, yet a powerful direct-current electro-magnet has been found of great service in ophthalmic surgery. Such magnets have been devised by Hirschberg, Schloesser, and Haab, varying in strength from a carrying power of one or two pounds up to over 300 lb. in weight. It is doubtful whether the extra large magnets are more useful than the medium-sized ones for extracting steel particles from within the eye.

Ozone.—Ozone is a condensed form of oxygen, the molecule of ozone containing three oxygen atoms instead of two, and it has a high oxidising power. It has a somewhat unpleasant smell, and may always be recognised in the neighbourhood of high potential electric machines when working, such as large static machines or high frequency machines, the brush discharge of the latter especially giving rise to its production. The lightning flash also generates ozone in its passage through the air; but all these electric agencies at the same time produce oxides of the atmospheric nitrogen, chiefly nitric oxide (N_2O_4), which is subsequently further oxidised into nitric acid. These oxides of nitrogen are very irritating and injurious to the respiratory tract, and it has been shown that more than a very small percentage of ozone in the air is fatal to small animals. Ozone has, however, a reputation amongst the public for revivifying properties, chiefly because it is found in traces in sea air, due to the electrical effects produced by evaporation. The so-called smell of ozone at certain seaside resorts is due entirely to decaying seaweed, fish, and sewage. Machines are constantly being advertised for the production of ozone, the principle of construction being to drive a current of air through the space between two glass cylinders, one being contained within the other. The inside of the inner cylinder is coated with tinfoil, which is connected to one pole of a strong induction coil, while the outer cylinder is surrounded with a number of metallic points which are connected to the other pole of the induction coil. This coil may be excited by dry cells like an ordinary faradic coil with an interruptor, or it may be driven by alternating current from the main. When in action a violet glow is seen in the space between the glass cylinders, and air driven through this space by means of a hand bellows, electric fan, or the pressure of an oxygen cylinder will issue from the discharge tube, highly charged with ozone. To avoid the production of nitric oxides an oxygen cylinder should be used, but in practice this is never done.

CHAPTER XII

ELECTRIC LIGHT BATHS AND X-RAYS

Electric light baths are used for two purposes: (1) to promote free sweating; (2) for the actinic effect of the light on the skin and subcutaneous tissues. For the former purpose incandescent lamps are used, and for the latter the arc and mercury vapour lamps. The difference between these two classes of lamps is that the heat rays or rays at the red end of the spectrum, which are useful in raising the temperature of a cabinet bath and thus of promoting diaphoresis, are present in considerable quantity in the spectrum of incandescent lamps; while the actinic rays which are present in the ultra-violet end of the spectrum are very scanty in the light of incandescent lamps. On the other hand, the light of the arc lamp is rich in ultra-violet rays, which have a very special effect upon the skin and subcutaneous tissues. Sunlight is comparatively poor in ultra-violet rays, which are mainly absorbed by the upper layers of the atmosphere before reaching the earth.

RADIANT HEAT

Radiant heat baths have been especially recommended for subacute and chronic rheumatic affections, infective and other forms of polyarthritis, gout, neuritis, sciatica, some forms of toxæmic headache, and chronic nephritis with arterio-sclerosis. They are contra-indicated in cases of myocardial weakness or aortic valvular disease of the heart. Radiant heat baths may be applied in the form of cabinet baths, in which the patient, after undressing, sits on a chair covered with a blanket or Turkish towelling, surrounded with incandescent electric lamps, which thus raise the temperature to 150° F. or even 300° F. All parts of the body being thus exposed to the radiant heat, except the head, which projects through a hole in the top of the bath, sweating usually commences within five minutes, and may be varied in amount according to the number of lamps turned on and the duration of the bath. Fifteen to twenty minutes usually suffice. After the bath, the patient must be carefully rubbed down with soft towels, and allowed to rest and cool down for another twenty minutes before dressing.

Ordinary incandescent lamps are not entirely free from ultra-violet rays, and a certain amount of burning of the skin may be produced by them. The large incandescent lamps made by the Dowsing Company are stated by them to be entirely free from violet and ultra-violet rays, and to be especially rich in heat rays from the red and yellow end of the spectrum.

Intense radiant heat damages the eyes in course of time, drying up the lens and causing cataract. Bottle finishers are thus subject to cataract starting at the posterior pole of the lens. Their work necessitates frequent exposure of their eyes to the intense heat and glare of the glass furnaces.

FINSEN LIGHT

The Finsen light was first applied by the Danish inventor of the treatment to cure lupus, by means of focussing sunlight through water lenses pressed on the skin to render it anæmic and thus allow the rays to penetrate. Partly because sunlight is less rich in ultra-violet rays than the electric arc lamp, and partly because of its inconstant supply, large electric arc lamps were devised by Finsen for the treatment, the light being focussed on the part requiring treatment by telescopes through quartz lenses, cooled by a stream of cold water. Quartz allows almost free passage to ultra-violet rays, and is much better than glass. This light is, therefore, called the Finsen light, and the arc lamps originally used were of great power, requiring as much as 80 ampères of current.

Smaller and more convenient lamps are now more commonly used, such as the Finsen-Reyn, the Lortet-Genoud, Strebel, and their modifications. These are brought close to the patient and can be used for only one person at a time, while the large Finsen arc lights are sometimes fitted with four telescopes for the simultaneous treatment of four patients. Of the small lamps the Finsen-Reyn is undoubtedly the best. This requires about 20 ampères. The addition of iron to the carbon or the substitution of iron for the carbon electrodes has been shown to largely increase the proportion of ultra-violet rays in the light given off, and more readily produces a superficial reaction of the skin, but it is less efficient for lupus.

The light treatment has been, and is still, extensively used for the treatment of **lupus**. Owing to the concentration of light required, the part being rendered anæmic by the pressure of the quartz lens on the skin, and the length and number of exposures required, the Finsen light treatment for lupus has been, to a large extent, superseded by X-rays and by the newer vaccine treatment for tuberculosis devised by Sir Almroth Wright. The light treatment is undoubtedly curative of lupus; but the great objection to its use, besides the length of time required, is the difficulty or impossibility of making the light penetrate sufficiently deeply into the tissues. The skin and subcutaneous tissues are rendered as anæmic as possible by pressure, because the light is entirely arrested and absorbed by blood ; but even with this precaution the penetrative power of the light is not to be compared with that of X-rays. For this reason the Finsen light fails, as a rule, in the treatment of epithelioma, rodent ulcer, and other forms of malignant disease of the superficial structures, and X-rays are far preferable.

Rodent ulcer has been already referred to as being treated with *zinc ions*, round button-shaped electrodes of bare zinc being used with the positive pole and a constant current of 5 to 10 ma.

Chronic skin affections, such as varicose ulcers, gouty eczema, boils, etc., have been shown to benefit by the light treatment. Certain wave-lengths of the ultraviolet rays have been found to be bactericidal, and this may be partly the reason for the improvement. Strong arc lamps, with iron or carbon-iron electrodes, are mounted on a portable frame which can be rotated in any direction and can be brought close to the patient. After three minutes or more the skin usually shows signs of a reaction, the part becoming reddened and slightly swollen and painful, so that the lamp must be removed further off. The more chronic skin diseases, such as an old-standing refractory case of gouty eczema, will show no reaction, perhaps, for the first half-dozen applications ; but once there has been reaction, the light can be borne only for a short time, and the eczematous patch rapidly begins to heal up.

Lumbago, chronic muscular rheumatism, and **sciatica** may also be beneficially treated by means of the arc lamp and ultra-violet rays, in conjunction with the incandescent lamp cabinet. These cabinet baths are usually made with a door specially fixed for the attachment of a small arc lamp, or the rays of the larger and stronger arc lamps can be applied to the patient's back or thighs by opening the door through which he enters the cabinet. For lumbago, the best combination is the incandescent cabinet bath in conjunction with the arc lamp applied in this manner, followed by a galvanic hydro-electric bath and massage.

MERCURY VAPOUR LAMP

This is sometimes known as the Cooper-Hewitt or the Bastian light. It consists of a long glass tube, two to three feet in length, which is exhausted of air, but contains two or three ounces of mercury and mercury vapour. Platinum wires fixed in carbon blocks form the terminals at the two ends of the tubes by means of which the current is led to the mercury. They are driven by direct current, usually from the electric light mains, using appropriate resistances. The lamp is started by tilting it slightly with the negative pole below, so that the mercury makes momentary contact between the two poles, when some of it is instantly vaporised, the vapour acting as a conductor for the current, which causes the whole length of the tube to glow with an intensely bright light, slightly greenish-blue in colour. The spectrum of this light is remarkable in containing practically no red rays; but it is rich in green, blue, and violet, as well as ultra-violet rays. Owing to the absence of red rays in the light, objects coloured red in white light will appear black when viewed by a mercury vapour lamp, and the hands and faces of people appear a bluish livid hue, peculiarly corpse-like. Green-coloured objects, such as palms and ferns, will, however, appear quite natural in this light, owing to its richness in green rays.

In order to overcome, for lighting purposes, the objectionable absence of red rays in the light, it is customary to surround a mercury vapour lamp with a ring of three or four ordinary incandescent lamps, but this device is quite insufficient. It is, of course, worse than useless to surround the lamp with a red shade, as that would only result in blocking out all the light, a red shade only appearing red in ordinary light because it absorbs all the other coloured rays, and reflects or transmits only the red rays. Owing to this objection, the light has not come into general use, although it is extremely cheap, cheaper than incandescent gas.

In places such as dockyards and railway jetties, and for signalling and lighthouses, it may, however, prove a success, when a convenient form of the lamp has been worked out. It consumes only two-thirds of a watt in energy for every candle in power, being thus nearly six times more efficient than ordinary incandescent lamps, an ordinary 16-candle lamp requiring 60 watts Thus, with electricity costing 6d. per unit, or kilowatt hour, a 100-candle-power mercury vapour lamp could be lighted for two and a half hours at a cost of only one penny.

Owing to the richness of this light in ultra-violet rays, it is proving of service for therapeutic purposes, as described above, and a special lamp, the Uviol lamp, has been devised with this object in view. This lamp, made of a special glass, by Dr. Schott in Jena, permits of the passage of ultra-violet rays, which are mostly arrested by the ordinary glass lamps ; but spectacles are necessary to use with it on account of the irritating effect of these rays on the eyes. This is liable to produce intense conjunctivitis, such as may be caused by the light of a strong arc lamp, or the "snow-blindness" acquired by climbing in high altitudes over snow fields. It has already been said that a large proportion of the ultra-violet rays of sunlight are arrested in the upper layers of the atmosphere. Since, for every 1,000 feet of altitude, the barometrical pressure falls about an inch, and the air becomes proportionately more rarified, the sunlight is much richer in ultra-violet rays on high snowfields, which at the same time reflect the light into the eyes so intensely. Goggles for the protection of the eyes from conjunctivitis due to exposure to snow, arc lamps, or mercury vapour lamps, should therefore be made of the reddish-yellow non-actinic glass, instead of blue or smoked glass, as it is the rays in the blue and violet end of the spectrum that cause the irritation and chemical effects.

For **therapeutic** purposes, three Uviol lamps are mounted on a stand, with reflector, rheostat, and ampèremeter. Better even than the Uviol glass for allowing ultra-violet rays to pass is quartz, and now quartz lamps, water-cooled, with quartz lenses, are made for mercury vapour lamps. They stand greater heat than the glass lamps, and generate much more powerful ultra-violet rays.

The **Nernst** lamp gives an intense white light, due to a filament of yttria and zirconia being heated by the passage of the current. This filament is not a conductor of electricity when cold, and therefore the lamp does not light up at once, and is provided with a heater, automatic cut-out, and resistance.

The **flame arc** gives the most intense form of light, next to the Leyden jar high tension spark. It is a great improvement on the old form of open arc light, and its efficiency is the highest of all electric lamps, being only .28 watts per candle. Instead of the carbons being perpendicular to each other, they are inclined towards each other at an angle pointing downwards, and the arc is blown out into a flame by an electro-magnet below a reflector, an arrangement which distributes the light much better. The yellow flame arc is rich in red and yellow rays, due to the carbons being impregnated with calcium fluoride. Rays from these lamps penetrate water vapour much better than the shorter vibration rays from the ordinary arc lamp, and are therefore much better in foggy weather; they are, accordingly, being largely used for street lighting, as in Oxford Street. Barium salts make the flame arc white, while a pink light is produced by impregnation of the carbons with strontium salts, as in the arc light on the top of "The Playhouse" in Northumberland Avenue.

The **Moore** light is an exceedingly effective light for large areas. It consists of a long glass tube about 1¾ inches in diameter, of any shape and length up to 200 feet, partly exhausted of air, and illuminated by the passage of a high voltage alternating current. The light somewhat resembles the glow inside the vacuum electrodes of a high frequency apparatus. An alternating current of 50 cycles and 100 to 200 volts is sent through the primary of a high tension transformer, the secondary yielding alternating current at a pressure of several thousand volts. This is connected to the glass vacuum tube by graphite cup electrodes, with an additional mercury-carbon automatic valve for admitting small quantities of air to the tube, at intervals of about one minute, as the vacuum is raised by the passage of the current. The efficiency of the light is 1.78 watts per candle, about 12 candles of light being obtained from each foot of tube. Different-coloured lights may be obtained from it; with ordinary air admitted by the valve, the tube glows rose-pink, as in the installation in the Savoy Hotel Strand courtyard. If the air is passed over phosphorus, the light is golden yellow; if pure nitrogen only is admitted, the light is yellow; with pure carbon dioxide the light is white.

Appended is a list of the principal sources of electric light, arranged in the order of their efficiency in watts per candle-power :—

Flame arc	.28	watts per candle.
Mercury vapour lamp .	.64	,, ,, ,,
Open arc	.75	,, ,, ,,
Osram lamp . . .	1.25	,, ,, ,,
Nernst lamp . . .	1.4	,, ,, ,,
Tantalum lamp . . .	1.7	,, ,, ,,
Moore light . . .	1.78	,, ,, ,,
Carbon incandescent lamp .	3.75	,, ,, ,,

COLOURED LIGHT

Red light is said to prevent the suppuration of smallpox vesicles, and the consequent permanent scarring. This is ancient knowledge, for the Black Prince is said to have been treated for smallpox by red curtains being drawn round the bed. This belief is founded on truth, for red curtains would exclude the rays from the blue end of the spectrum, thus shutting out the ultra-violet actinic rays which especially affect the skin. Cases have been published of improvement of **chronic ulcer** and of **gangrenous stomatitis** by exposure to red light from a 16-candle-power lamp, with a red globe and reflector. This is probably due to the exclusion of the blue rays, for the red glass cannot add any red rays to a light which did not possess them before; it merely filters off the other coloured rays.

Blue light. Exposure to blue light for several minutes has been said to produce a curious sedative effect and anæsthesia, so that minor surgical operations may be done under its influence. Pain from joint effusions or in arthritis is said to have been relieved, and it is usual to insert a deep blue glass window into the side of an electric light cabinet bath so that the light from an arc lamp may be directed through it upon the joints of a patient being treated for rheumatism or other forms of arthritis. Its sedative effect upon mental states is also said to be pronounced, producing calm, followed by sleep.

RÖNTGEN RAYS

An enormous amount of work has been done in connection with these rays, or X-rays, as their discoverer Röntgen named them, during the past twelve years. It was the work of Crookes on the phenomena of electric discharge in tubes highly exhausted of air that led to Röntgen's discovery. If such a tube, having platinum terminals sealed into its ends, be exhausted until the air pressure is only one ten-thousandth part of an atmosphere, it is found that the resistance of the tube to the passage of high-pressure electrical currents of 50,000 to 100,000 volts or more is changing. Before exhaustion, the current jumps across the air space between the terminals in a series of intensely bright sparks; but when the exhaustion reaches the degree mentioned above, it is found that sparks are no longer passing, but that the tube is filled with a glow of light. A beam of light appears to issue from the kathode, which is surrounded with a dark space, while a striated cloud of light surrounds the anode or positive pole. When the exhaustion of the tube is carried still further, the dark space around the kathode extends farther along the tube until at last it strikes the glass at the other end, producing a beautiful phosphorescence—green if the tube is made of soda glass, blue if the glass contains lead.

This phosphorescence of the glass at the anode end of the tube is due to a stream of rays issuing from the kathode, as can be proved by shadows of solid objects in front of the kathode being thrown on the phosphorescent glass. These rays were called the kathode rays by Lenard, who discovered in 1894 that they could pass out of the tube into the outer air through an aluminium window let into the glass bulb opposite the kathode. They consist of a beam of infinitely tiny negatively electrified bodies called corpuscles, or electrons. The smallest chemical atom known is the hydrogen atom, the atomic weight of hydrogen being taken as about 1; but the hydrogen atom contains 1,000 electrons, though each electron, when flying free, carries a charge of negative electricity equal to the electrical charge carried by a whole hydrogen atom. Lenard discovered that these rays of electrons penetrated substances in proportion to their density, thus differing from light rays, to which many light substances (such as cork and aluminium) are opaque, though heavier substances (such as water and glass) are translucent. These Lenard rays, consisting of a beam of corpuscles, can be deflected by a magnet; and by this means calculations have shown that these tiny bodies reach the enormous speed of 10,000 to 90,000 miles per second, or about half the speed of light, which is 186,000 miles per second. The rays, when they strike objects, produce X-rays, which are very different from the rays which give rise to them. X-rays cannot be deflected by a magnet, and they do not consist of electrons or corpuscles, but are probably a peculiar form of pulsating vibrations in the ether set up by the impact of the beam of corpuscles upon the object which they strike. Thus the impact of the kathode rays or beam of corpuscles issuing from the kathode in the Crookes tube, by striking upon the glass at the other end causes the glass to phosphoresce, and produces a new set of rays, the X-rays, possessing very different properties. The X-rays travel with the same velocity as light, but cannot be polarised like ordinary light; they have enormously greater power of penetration through substances, in proportion to their density or atomic weights; and they can affect photographic plates through many inches of solid wood or aluminium, though they are more quickly arrested by the denser metals such as lead, gold, and platinum. Unlike ordinary light, X-rays are invisible to the eye, and cannot be deflected by a prism or lens.

Various forms of Crookes tubes have been designed for the production of X-rays, but the essentials of all are the same. The modern focus tube is about a foot long, made of soda glass or with a soda glass window to allow of the escape of the X-rays, which are stopped by lead glass. The tube is blown into a bulb in the middle, which contains two anodes, one made of aluminium, the other of platinum. One of the anodes is placed directly opposite the kathode, and is therefore called the anti-kathode, and it is made of copper coated with platinum, in order to withstand the intense discharge of the kathode rays upon it. Its face is inclined at half a right angle to the perpendicular line drawn from the face of the kathode. The latter pole is made of aluminium, and its face is concave, so as to focus the discharge of kathode rays which it gives off. If platinum were used for the kathode it would become gradually disintegrated, the kathodal rays carrying off minute particles of the metal, and blackening the tube; but this does not occur with aluminium to anything like the same extent. The distance of the anti-kathode is so arranged that the kathode rays are almost exactly focussed upon it—not quite exactly, because in that case the platinum would soon be melted and the tube rendered useless. The aluminium anode is sealed into the bulb a little to one side of the anti-kathode, and it is usual to connect the anode and anti-kathode together outside the tube by a wire, so that they both function as anodes, though this is not necessary, the main function of the anti-kathode being to serve as a target upon which the kathode rays are focussed. The tube is then highly exhausted of air, the pressure being reduced to one-millionth of an atmosphere. In order to excite this X-ray tube, a unidirectional current of high potential must be driven through it in order to overcome its resistance and force through it a steady stream of kathode rays. Such a high potential current of 50,000 to 150,000 volts, which is necessary, may be obtained from one of three sources: (1) a 10- or 12-inch induction coil, worked by a direct current at 12 or more volts, interrupted 40 or more times per second by some form of mechanical or electrolytical interruptor; (2) an alternating street current, transformed by a step-up transformer to a high voltage, and converted into a unidirectional current by means of a mechanical or valve tube rectifier; (3) a large static machine.

On the whole, there can be no doubt that the best and most efficient apparatus for producing X-rays is a good spark coil by a reliable maker, giving a 12-inch spark, though a 16- or even 20-inch spark coil is better. A convenient and most usual way to drive these coils is to use a set of accumulators capable of giving about 50 ampère hours at a pressure of 24 volts. Large induction coils requiring such heavy currents need a special form of interruptor to break the current supplied to the primary windings, as a spring interruptor of the type usually fitted to the small Ruhmkorff faradic coils does not work smoothly enough, and the intensity of the spark on the platinum points of the interruptor soon burns them away.

The two most usual forms of interruptor used in this country are the Mackenzie Davidson and the mercury jet. The **Mackenzie Davidson** consists of a spindle set at an oblique angle, carrying a metal fin fixed at a right angle to its lower extremity. The spindle passes obliquely through the top of a box containing mercury and rectified spirit, and is rotated by a small DC motor wound for 12 or 24 volts, so that the metal fin on the end of the spindle dips in and out of the mercury as it is revolved. The spirit floating above the mercury serves to extinguish the spark and to increase the suddenness of the break. This is a very simple and efficient form of interruptor for low voltages, and costs about 6½ guineas.

The **mercury jet interruptor** is better than the former, especially for voltages of 100 to 240; it consists of a centrifugal pump driven by a DC motor, which delivers a jet of mercury upon a revolving disc carrying alternately copper discs and insulating spaces of alcohol. A convenient form of self-contained motor and mercury turbine break is sold by Messrs. Gaiffe, of Paris, under the name of "interrupteur autonome." It is suitable for all kinds of coils.

Both the Mackenzie Davidson and the mercury jet interruptors require cleaning out at intervals, according to the extent to which they are used, as the mercury becomes very dirty and churned up. This should be done under a tap of running water. With both these forms of interruptor, it is necessary to have a condenser fitted to the coil.

One of the best and most convenient interruptors is the **coal-gas mercury break** supplied by Messrs. Watson, of High Holborn, and commonly spoken of as the "Gas-Break" (Fig. 24). This instrument is the invention of M. Béclère, of Paris, and has not long been on sale, but promises to supersede all other forms, as it is small and portable, quiet in running, clean, and equally efficient with all voltages of current. It is, in principle, a combination of a magnetic interruptor with a mercury turbine jet, of novel design, the motor and turbine being combined in one piece, with no pulley to get out of order. Rather less than 1 lb. of mercury is required, and this keeps quite clean, even after continual running. The special point of the interruptor is that no spirit or petroleum is used above the mercury for the extinction of the spark; but coal-gas is used to fill the whole of the reservoir A, which is made practically air-tight, the gas being continually fed to the interruptor from a gas-bag or through rubber piping from a gas-jet. Very little gas is required, only 1-10th of a cubic foot in several hours, as the gas is not consumed and the leakage is very slight. Before commencing to use the apparatus, the reservoir A above the mercury must be filled with coal-gas or hydrogen. This is done by attaching a rubber tube connected with a gas supply to one of the two

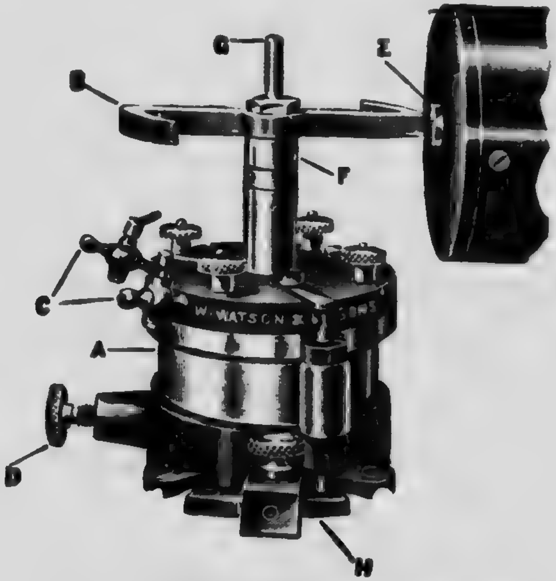


Fig. 24.—Béclère coal-gas mercury break.

cocks C, and running the gas through for about 10 seconds, in order to drive out all the air through the other cock, which is left open and then closed. The mercury is thus not churned up as in the spirit and petroleum breaks, and it will keep clean even after months of running.

The shaft of the turbine jet is prolonged above the top of the metal reservoir, and has affixed to it a horizontal pair of soft iron arms B. The interruptor is so mounted on the stand of the coil as to bring B on a level with and in close approximation to, but not quite touching the protruding metallic core E of the primary coil. The current being switched on, the milled head G of the turbine jet is twirled round by hand, which starts the jet and interrupts the current to the coil. The magnetic core of the primary thus intermittently attracts the soft iron arms B, and so keeps up the rotary motion once it is started by hand. The speed of the interruptor can be varied from slow to fast while it is working, by moving the handle D through a small arc of a circle, which alters the distance at which the attractive power of the core E ceases to be exerted upon the soft iron arms B.

Mr. Leslie Miller, of Hatton Garden, fits a *mica disc valve* above the Béclère break, in order to suppress the "closing current" in the secondary circuit to the focus-tube. It consists of a revolving mica disc fixed to the break spindle, which is interposed in a gap in the secondary circuit so that at the moment of break the current can pass the gap through a hole in the mica plate, the gap being less than a quarter of an inch, while as the disc continues to revolve, at the moment of "make" the mica disc is interposed in the path of the "closing current," a resistance about equal to that of a 4-inch spark gap. This arrangement has the advantage of the ordinary spark-gap for the suppression of the closing current that the gap in the path of the current at "break" is very short, and thus offers less resistance to the necessary break current in the proper working of the tube.

The **Wehnelt, or electrolytical interruptor,** is an extremely efficient one, but it makes a considerable noise. It cannot in practice be used with accumulators, as it works best with not less than 60 to 80 volts, and 15 to 20 ampères. It consists of two electrodes—a platinum point and a large lead plate—immersed in a glass vessel containing 16 ounces of strong sulphuric acid diluted with water to make a gallon of the dilute acid. The platinum point is connected with the positive pole, and the leaden plate with the negative of a direct current main supply, through a shunt rheostat, so that the voltage of the current supplied to the interruptor can be varied from about 30 to 100. These interruptors work very regularly and smoothly, if they are provided with means of regulation of (1) the surface of the platinum point, (2) the number of volts used in the primary circuit, (3) the degree of self-induction in the primary coil. The coil should have no condenser when used with the electrolytic interruptor. With a long platinum pin and a low self-induction in the primary coil, long and intense sparks will be obtained from the secondary, suitable for working a hard tube ; while with a short platinum and a high self-induction in the primary, the output will be low and suitable for use with soft tubes. One advantage of the electrolytical interruptors is that they require no cleaning ; but, on the other hand, they make a considerable noise, and it is best to keep them in another room, using a suitable switchboard apparatus to control them.

The action of the electrolytical interruptor is as follows : The platinum anode and the lead kathode of the cell are connected in series with the main supply and the primary windings of the coil. Owing to the small size of the platinum anode and the heavy current passing, the density of current at the platinum pin is very great, so that the platinum is soon heated up to incandescence ; thus, in addition to the liberation of oxygen by electrolysis at the platinum anode, the contact of the incandescent metal with the liquid generates a mantle of steam around it, thus suddenly breaking the current. At this moment the sudden breaking of the current in the primary generates a powerful extra current, owing to its self-induction, and this current sparks across the steam mantle to the platinum anode, the explosion of the spark and the chill of the surrounding liquid suddenly dissipating the insulating steam mantle around the platinum, and allowing the liquid to regain access to the metal pin, thus re-establishing contact and the flow of the current. This process is repeated with extreme rapidity and regularity, if the voltage and ampèrage of the current are sufficient. The cell, when working, gives out a peculiar shrill note, and a glow of rose-coloured light is seen to surround the platinum point. With continuous working, the temperature of the liquid in the cell is slowly raised to near boiling point, when the apparatus ceases to work properly ; for this reason large cells, holding a gallon of dilute sulphuric acid, are used, so that they will work, if required, for several hours continuously, without overheating. If the current is sent in the wrong direction through the cell, the platinum being then connected with the negative pole, blue instead of rose-coloured sparks appear at the point, and the platinum soon becomes destroyed.

The **alternating current** main supply may be used for the production of X-rays, in three different ways. (1) It may be employed to charge accumulators, and the direct current from the accumulators used to drive a coil in the ordinary way. In order to charge accumulators, the alternating current must be rendered unidirectional by some form of apparatus. This may be done in several methods : the main current may be used to drive an alternating current motor coupled to a DC dynamo, or a mechanical current rectifier with a vibrating hammer may be used to reverse the direction of every alternate wave, thus converting the current into a pulsating unidirectional current; these rectifiers may have an efficiency of as high as 80 per cent. Electrolytic rectifiers may be used, such as the Graetz aluminium cells, four of which in series will convert a 100-volt alternating current into a pulsating unidirectional current of about 80 volts, and this current, with an electrolytic Wehnelt interruptor, will give good results with a spark coil.

(2) A mercury jet interruptor may be combined with a synchronous alternating current motor, so that every alternate phase of the current is received upon the insulating alcohol, and the current collected by the copper strips is unidirectional. Such a combined motor and interruptor is manufactured by Messrs. Gaiffe, and described by them as "interrupteur autonome pour courant alternatif, système 'Blondel.'" It consists of a mercury turbine driven by a small synchronous alternating motor from the main; it is started by giving it a twist by hand, when it continues to rotate with increasing speed until its speed becomes synchronous with the periodicity of the driving alternating current. This takes about thirty seconds, and the unidirectional interrupted current delivered from it can be used directly to drive the coil, or it can be used to charge accumulators. An efficiency of 80 per cent. is claimed for it.

(3) The third way of using the alternating current to produce X-rays is by means of step-up transformers, raising the voltage of the current to 60,000 volts. With this apparatus no spark coil is necessary; but, since the high potential discharges from the transformer are alternating, it is necessary to render them unidirectional before sending the current through the X-ray tube. This is effected by two Villard valve tubes in series, which block the current in one direction. The apparatus gives a perfectly steady light upon the screen; but its output does not appear to be

as good as that of an efficient coil worked by the direct current, and though it will work well with a hard tube and for screen work, yet it is not recommended for photographic work, or for therapeutic purposes with low vacuum soft tubes, which require a heavy current. This form of apparatus is, moreover, very costly. The transformer cabinets for the alternating current main supply are the most powerful generators of high-frequency currents known. For this purpose the Villard valve tubes are taken out of the circuit and the current sent through a primary copper coil, or an Oudin's resonator. The effluve from this is more powerful than with a spark coil.

The **static machine** as a source of X-rays is scarcely to be recommended. For screen work with a hard tube it gives excellent results, the light being perfectly steady; but for X-ray photography and therapeutic work it is much too weak, the exposures necessary being from five to ten times as long as with a good coil. The current from the static machine is, however, perfectly unidirectional, and no valve tube will be necessary with it, and the focus tubes last very much longer than with a coil, as they are exposed to much less strain, and there is no destructive action of any closing current. The voltage of the current from a static machine, measured by the length of its spark, depends on the diameter of the plates and the speed of the revolution; whereas the volume of the output of current depends on the number of the plates and their diameter. With glass plates, at least eight will be required, with a diameter of 30 inches, to excite a focus tube at all satisfactorily (*see* p. 362).

If, therefore, a large static machine is required for therapeutic purposes, it may also be very conveniently made use of for the production of X-rays for screen work. The output of current from even a large static machine cannot compare with that of a good coil, and since for short exposures in X-ray photography it is a large milliampèrage of current, rather than high voltage, that is required through the tube, a good spark coil, driven off accumulators or the main direct current, with a good mercury jet or electrolytical interruptor, will prove far more satisfactory for general X-ray use. No spark coil gives a pure unidirectional current like the discharge from a static machine, and there is always a certain amount of closing current which is developed at the "make" as well as the larger volume of current developed at the "break." We have already referred to this current at make in the smaller induction coils used for faradic treatment. This closing current interferes with the clearness of the definition of the photographic picture, and it also shortens the life of the tube by making it "hard," that is to say, making the vacuum still higher and increasing its resistance to the passage of the current, by causing the occlusion of some of the residual gas. The resistance of the tube to the closing current may be less than that offered to the current in the right direction; the amount of closing current may even be greater than the break current, unless a valve tube is used. This may be shown by the needle of the galvanometer in the secondary circuit changing its direction after the insertion of a valve tube. The number of milliampères of current in the secondary circuit through the tube may be measured by an ordinary D'Arsonval galvanometer, and it will be found to vary from .5 ma. to 1 or 2 ma. As large a current as 10 ma. has been forced through a tube, but very few tubes will stand such a heavy current without being destroyed.

The closing current may be considerably diminished, or entirely arrested, by the use of a **valve tube** in series with the X-ray tube in the secondary circuit. These valve tubes are of different forms, but their principle of construction is as follows: a vacuum tube, somewhat smaller than an ordinary focus tube, with two aluminium electrodes sealed into the two ends, one being large and spiral-shaped, and placed in the middle of the bulb; the other small, with a concave face, and sealed in a narrow portion of the tube. The tube should also be furnished with a palladium wire osmo-regulator to control the vacuum. When the large spiral electrode is arranged as the kathode, the current will pass easily; but it will scarcely pass at all in the reverse direction. These tubes may be arranged either in series with the X-ray tube, so as to prevent the impulses in the wrong direction from reaching the tube, or they may be arranged in shunt with the X-ray tube, so as to carry off the impulses in the wrong direction, while preventing the proper impulses from passing through the valve tube and thereby forcing them to pass through the X-ray tube. When arranged in series, which is the usual way, the valve tube should be inserted between the kathode of the focus tube and the negative pole of the coil, having the large spiral electrode attached to the coil side, and the small electrode in the narrow end of the tube attached to the wire leading to the kathode of the focus tube. The focus tube should be at some distance from the valve tube, and also from the coil.

Instead of a valve tube, a **spark gap** may be arranged between the focus tube and the coil, using a brass point as the positive and a flat circular plate as the negative. Sparks will easily pass from the point to the plate when the point is the anode, but the current will be unable to spark across the gap from the plate to the point. If the plate is attached to the negative pole of the coil, and the brass point to the wire leading to the kathode of the focus tube, the current will spark across the gap easily from point to plate, while it is running in the right direction through the focus tube; but the closing current will be unable to spark across from the plate to the point, and thus the tube is protected.

It is to be remembered that the EMF of the closing current increases directly with the voltage and inversely with the amount of self-induction used in the primary windings. It is therefore best to keep the self-induction high, and the voltage in the primary as low as possible, which may be done with a coil provided with a variable self-induction switch. Another device to prevent the passage of the closing current is to cover the anti-kathode of the focus tube with a porcelain ring; this arrangement is fitted in Bauer's and Gundelach's tubes.

When the current is running smoothly in the right direction through the X-ray tube, the tube appears to be full of green air, with a brilliant green phosphorescence on the glass bulb opposite the anti-kathode if the tube is made of soda glass, bluish if the glass contains lead. If there is much closing current, the fluorescence is patchy and a bluish haze appears around the anode. Since the X-rays are generated at the anti-kathode by the impact upon it of the kathode rays, they are projected in straight lines from the surface of the anti-kathode in all directions within an arc of 180°, passing through the glass wall of the tube into the outer air. There is no advantage to be gained by so placing the focus tube that the plane of the surface of the anti-kathode is parallel to that of the object to be examined. If the vacuum in the tube is not sufficiently high, the tube is said to be "soft," and the green fluorescence is much brighter than with a hard tube. Occasionally the tube becomes too hard by continuous use, or by the action of the closing current, and then very little current passes, with much less green phosphorescence. Such a tube may often be made softer, that is to say, some of the occluded gases may be released within the tube by warming it over a spirit flame, or, better, by baking it in an oven for some hours.

Many tubes are now made with an **osmo-regulator** or other device for lowering the vacuum. The osmo-regulator of Villard consists of a thin-walled tubular palladium wire, sealed into a side branch of the X-ray tube or valve tube.

The outer end of the tubular wire is of course closed; and when the vacuum requires reducing, the wire is heated in the flame of a spirit lamp. Palladium has the property of becoming permeable to hydrogen when heated to a red heat, and the wire absorbs hydrogen from the flame, the gas being thus passed on into the tube. Such a regulator should be fixed in the Villard valve tube, which by constant use may become too hard, as well as the X-ray tube itself. After heating the palladium wire, it must be allowed to get quite cold before the current is again passed through the tube.

When an X-ray tube has been working continuously for some time, or especially if a heavy current is sent through it, the anti-kathode is likely to get red hot, and after a certain time gases are released from the hot metal, and the vacuum of the tube is lowered, and the tube may in this way become too soft. A tube that has become too soft may have the vacuum raised by switching the current through it for a short time in the wrong direction. This causes a discharge of minute particles of platinum, which absorbs the gases; but it is not a procedure to be recommended, as it soon ruins the tube by blackening it.

It is advisable, therefore, always to use a D'Arsonval milliampèremeter in the secondary circuit, as well as the Villard valve tube or spark-gap, and to have both the X-ray tube and the valve tube fitted with an osmo-regulator. Thus, care in not sending too heavy a current through the tube, at first not more than .4 ma., will prevent the vacuum from being lowered owing to excessive heating of the anti-kathode; while long-continued normal working, which slowly raises the vacuum, causing the tube to become "hard," can be quickly adjusted by heating the projecting platinum wire of the osmo-regulator. A good X-ray tube may thus, with care, last a very long time. Several of the more expensive focus tubes have air-cooling or water-cooling devices for preventing overheating of the anti-kathode. If this should occur, and cause the tube to become too soft by liberation of gases, it will be best to put it away for several weeks or months, and often the tube will return to its normal degree of hardness, the gases becoming again occluded.

In course of time, the glass of the focus tube turns violet-coloured, where it is exposed to the green fluorescence of the X-rays.

Good focus tubes are those of Muller, but perhaps the best are Chabaud's.

Recently **tantalum** focus tubes have been made by Messrs. Siemens, having a coating of tantalum instead of platinum on the anti-kathode. This is the same metal that is used for the wire filament in the tantalum incandescent lamps, and owing to its higher melting point, it resists the bombardment of the kathodal rays better than platinum. These tubes cost £3 15s., but stand a heavy current well, and are made for either air or water cooling.

The focus tube must be attached to the two terminals of the secondary coil by wires, or some form of metallic conductor. A usual and efficient, but clumsy way is to use the so-called high-tension wiring, as employed for motor-cars, copper wire covered with a very thick layer of insulating material, and to have two lengths of several yards, so that the wires can be suspended from the ceiling to the focus tube, which can thus be moved about easily within a certain radius. The best way of connecting the coil to the focus tube is to use two metal flat wire conductors, coiled on a circular spring, and fastened to the terminals of the coil. These resemble the spring metal-measuring tapes commonly sold, and the tape is pulled out and instantly fastened to the terminal on the tube, forming an ideal connection, which does not hang in festoons, and thus cause short circuits. They are sold by Messrs. Gaiffe, of Paris.

X-rays, being produced by the impact of the corpuscles of the kathode rays on any hard substance, such as the platinum anti-kathode of the focus tube, do not consist, like the kathode rays, of material particles, and cannot be deflected by a magnet, but probably somewhat resemble light waves. Light waves are continuous transverse vibrations in the ether, the wave lengths differing with the colour of the light, being longest at the red end of the spectrum and shortest at the violet end. X-rays are probably not continuous, but pulsatile vibrations in the ether, and they have a very much shorter wave length than light, being about 2,000 times shorter than the wave length of green light (*see* p. 364). Probably the shorter the wave length the more penetrating the ray, and the higher the speed of the kathode ray the more rapid will be the ethereal oscillation produced by it at the anti-kathode; that is to say, the more penetrating is the X-ray produced. Hence the gamma rays of radium, which are in reality X-rays, as we shall see presently, are the most penetrating of all rays.

X-rays in many respects resemble the ultra-violet rays, and in all probability they belong to the same order of phenomena. They ionise the air through which they pass, and so they will discharge an electrified body, whether the charge upon it is positive or negative. It will be remembered that the kathode rays, or Lenard rays, consist of corpuscles negatively charged, thus differing electrically from X-rays. The corpuscles of the kathode rays are not set free from the metallic surface of the aluminium kathode, as it has been shown that prolonged working of an X-ray tube does not cause any loss of substance of the kathode. Moreover, if the corpuscles comprising the kathodal rays were derived from the metal kathode the vacuum of the tube would gradually sink, instead of the tube becoming slowly harder, as it does. No doubt, the exhaustion of the tube of air, when carried to the point of high vacuum of the X-ray tube, sets free numbers of corpuscles or electrons from the gaseous molecules of the residual air, which, having a negative charge, are violently repelled from the negative pole towards the anode. The greater the degree of exhaustion of the tube, the easier path will the electrons have for their flight, and the more violent will be their impact upon the anti-kathode; that is to say, the harder the tube the more penetrating will be the X-rays generated at the anti-kathode by the impact of the kathode rays. At the same time, the harder the tube the fewer gaseous molecules and the fewer available electrons within the tube to generate the kathode rays; and, therefore, with the same electromotive force of the current traversing the tube, there will be fewer electrons in the kathode rays to strike the anti-kathode in a given time, and the output of X-rays will be less in quantity, though, as we have seen, their quality will be more penetrating. If, at the same time as the tube grows harder, the voltage of the current is increased, the kathode rays will be increased, and the output of X-rays may be prevented from diminishing. Constant use of a tube, unless it is overheated, gradually hardens the tube by occluding the residual gases in the glass walls; hence the number of electrons available for carrying the kathode rays will be too few, with the available voltage, to produce any appreciable effect upon the anti-kathode, and the tube is said to be too hard for that particular coil. With a more powerful coil the tube may still give very good results, owing to the higher voltage of the current. For this reason, a large coil of 16-inch or 20-inch spark is preferable to a smaller one, as although its spark gap can be adjusted to the softest tubes, yet tubes that would be too hard for use on a 10- or 12-inch coil may be made to give very good results. More powerful coils still, giving sparks longer than 20 inches, are at present unnecessary, and will not shorten the time of photographic exposures, as no tubes are yet made which will stand the full power of coils giving thick white sparks of 30 to 40 inches in length. Further improvements are necessary in the tubes, not in the coils.

It is clear from what has been said that a soft tube will provide a larger quantity of X-rays than a hard tube, though the rays will have less penetrating power. For radiotherapeutic purposes, therefore, and for photographing the less dense tissues, such as a hand or an arm, a soft tube will be preferable to a hard tube. In radiotherapy it has been shown that only the rays which are arrested by the tissues have any action upon them, and, therefore, it is only the rays of low penetrative power provided from soft tubes that produce any effect upon the skin or other tissues. The more penetrating rays from the harder tubes have little or no therapeutic effect. Clearly, therefore, means for deciding on the dose and the quality of the X-rays afforded by a given tube and coil are necessary if anything like accuracy is to be obtained in our results. These means are supplied by the following devices :—

1. A finely graduated **milliampèremeter** in the secondary circuit to measure the amount of current passing through the tube. This will not give a reliable reading unless the current is properly rectified by a Villard valve tube or a spark gap in the circuit.

2. A **radiochromometer,** such as that invented by Benoist; or Belot's, or Wehnelt's modification of Benoist's, called a crypto-radiometer, to demonstrate the penetrating capacity of the X-rays given by the tube. This device depends upon the fact that aluminium is very much more permeable to the highly penetrating rays from hard tubes than it is to the rays from a soft tube, while silver varies much less in its permeability. The instrument consists of a thin piece of silver, which can be compared with varying thicknesses of aluminium. With a medium soft tube, No. 5 of the aluminium will transmit the same intensity of light as the silver when viewed on the screen; while with a very hard tube the thickest piece of alu-

minium (No. 12) will appear of the same brightness as the silver.

3. **Sabouraud's pastilles** of platino-cyanide of barium, or Holzknecht's pastilles, which by a change in colour indicate the dose of X-rays applied. The colour turns from white to yellowish-brown, if shielded from the daylight, and the colour is then compared with a standard tint.

4. **Kienböck's quantimeter** is another apparatus for determining the dose of X-rays administered, and is said to work well.

5. The **spintermeter,** or adjustable spark-gap. This is a spark-gap between two brass knobs arranged in parallel with the tube. The current is turned on, and the knobs are brought together until a stream of sparks passes, and the tube goes dark owing to the alternative path for the current being open. Then gradually open the spark-gap until sparks just cease to pass, and the tube glows brightly once more. The measured distance between the brass knobs is then the equivalent spark-gap for that particular tube. This method is much more empirical than the galvanometer in the secondary circuit, which has practically superseded it.

6. The **osmo-regulator** of Villard—a device already described, by which a projecting tube of palladium wire is heated, the vacuum in the tube being lowered by the tube absorbing hydrogen from the flame. By using the osmo-regulator, and checking it with the radiochromometer of Benoist, the penetrating quality of the rays and the hardness of the tube can be kept constant; while the milliampèremeter in the secondary circuit will indicate the rate of emission of the X-rays, and the pastilles of Sabouraud or Holzknecht will indicate the amount of the dose delivered. By these means radiotherapy has emerged from the empiric stage, and is now firmly grounded on a scientific basis; so that it is possible to reproduce given conditions, and

again produce identical results. Until these instruments of precision were used, for the first few years of the medical use of X-rays the results obtained were most irregular, and X-ray dermatitis, X-ray burns, and ulcers were distressingly common, while now happily they are extremely rare and capable of being avoided.

X-rays have the property of causing certain substances to fluoresce, although the rays are invisible to the eye. Platino-cyanide of barium is such a substance, becoming slowly turned brownish by exposure to the rays, and losing its normal yellow colour; when exposed to the daylight, the normal colour more or less returns. **Fluorescent screens** are made for X-ray work, coated with this substance; the screen should be covered with a sheet of lead glass on the side turned away from the tube, for the double purpose of protecting the smooth surface of the screen from being scratched, and also to stop the further passage of the X-rays to the observer. **Intensifying screens** of tungstate of calcium are also sometimes used for increasing the effect of the rays on a photographic plate. The screen is arranged with its coated surface of the fluorescent salt next to the film on the plate.

Owing to the penetrating power of the X-rays through substances in proportion to their density, they are extremely useful for determining the condition of the bones and their relation to the soft parts; the presence in the tissues of metal, needles, coins, pieces of glass, etc.; and for accurate definition it is advisable to use a **diaphragm** close to the tube, so as to allow only the central beam of rays to pass. For the proper diagnosis and setting of fractures and dislocations they are invaluable; while in medical practice they are often of great service in demonstrating aneurysm of the aorta, consolidation of the lung, pleuritic effusion, empyema, pneumothorax, mediastinal tumour, etc. Stone in the kidney or ureter is also one of the most useful demonstrations that the X-rays are capable of; while osteo-arthritis of the spine or larger joints, or sequestra in the bones, may be well shown by means of suitable tubes. For determining the shape and size of organs such as the heart, an instrument called the "**orthodiagraph**" was invented by Dr. Levy Dorn. The central beam of the rays only is used, and the apparatus is so fixed that the tube behind the patient and the pencil carrier in front move together. This instrument is somewhat cumbrous and costly

The penetrating power of the X-rays generated by a particular tube depends entirely on the speed of impact of the kathode rays upon the target of the anti-kathode. If the vacuum in the tube is high, then the corpuscles or electrons of the kathode rays find less obstacles in their path; while at the same time the electrical resistance of the tube is heightened, and it requires a greater EMF of the current to overcome it. The higher the speed of the kathode rays, the greater will be the penetrating power of the X-rays developed by their impact upon the anti-kathode, and therefore the more powerful the induction coil the greater will be the power of the X-rays it produces to penetrate opaque tissues. Care should always be taken not to place the focus tube near the induction coil, because the magnetic action of the iron core would deflect the stream of kathode rays in the tube away from the anti-kathode, and so prevent it from focussing the X-rays.

The degree of vacuum that is necessary to produce the best effect with the X-rays will depend upon the particular purpose for which it is required. A tube that is very good for photography or for therapeutic purposes is generally much softer than one that gives a good picture upon the fluorescent screen; while a tube to give a screen picture of an abdomen, shoulder, or hip must be much harder than one that is only required to give a screen picture of a hand. The point to be remembered is that the harder the tube—that is to say, the higher the voltage of the current and the more violent the impact of the kathode rays upon the anti-kathode—the more penetrating are the X-rays produced, and the less differentiation will be shown between soft tissues and the harder tissues, such as the bones. For screen work, therefore, to examine a chest it will be necessary to use a tube of sufficient hardness, and a coil of sufficient power, to give X-rays of enough penetrating power to pass through the lungs and chest walls, and show a bright light on the screen through normal lung tissue. If a tube of the right degree of hardness be chosen, usually a medium tube, the normal lung will appear bright; while the ribs, heart, aorta, and liver will throw dark shadows, as will also consolidated lung, aneurysm, or pleuritic effusion, especially an empyema. If too hard a tube be chosen, the penetrating power of the X-rays will be so great that the denser structures, as the ribs and heart, will throw only faint shadows, so that it will be difficult to differentiate them from the bright, normal lung.

For photography, on the other hand, a softer tube is better, because the X-rays generated by it differentiate more between soft and dense tissues; and although the picture would not be brilliant enough to show up on a screen, yet beautiful negatives may be obtained with such a tube, because the continued action of the rays on the sensitive plate is cumulative, though the effect upon the retina only corresponds to the degree of stimulation at the moment. Finer shades of difference may often thus be brought out by an X-ray negative than can be seen upon the screen, such as the shadow of a renal calculus, or a stone in the ureter, a sequestrum in bone, etc. Moving parts, such as the lungs, diaphragm, heart, and aorta, however, often show better upon the screen, unless special precautions are taken to get the patient to hold the breath during the whole period of the exposure of the negative to the rays. This may be done by fixing the negative in position, making the patient take two or three deep breaths and then hold the breath at a given signal, turning on the current at the same moment for about twenty seconds, then switching off the current and allowing the patient to take a few more breaths; then he holds the breath again as nearly as possible in the same position of respiration at a given signal and the rays are turned on again; and so on until the required amount of exposure of the negative has been given. By this means the respiratory action upon the displacement of organs such as the kidney may be almost eliminated. A similar result may be obtained by an electric switch actuated by the respiratory movements at full inspiration, starting the coil and a time clock.

Tubercular consolidation of the lung does not, as a rule, show up well on the screen or in a negative, and, in my experience, physical signs are usually well marked before any pulmonary consolidation can be detected by the X-rays in cases of phthisis. I have, however, once or twice obtained help from the screen in diagnosis of pulmonary tubercle before the appearance of any physical signs could be recognised. Tubercular cavities usually show up well as dark shadows, with sometimes a lighter centre, while a pneumothorax appears brighter than the normal lung.

In the diagnosis of **aneurysm of the thoracic aorta** and mediastinal tumour, the X-rays are of the utmost use, and may often lead to a positive diagnosis of the condition while the physical signs are still misleading and equivocal. The screen should be well pressed against the patient's chest, as the picture will appear brighter; and after the observer's eyes have become accustomed to the darkness the details will be much more distinct. The pulsation of the heart and aorta will be visible, while an aneurysm is usually obvious on account of its large size. Sometimes it will be better seen from the front, sometimes from behind. Owing to the normal curve of the aorta to the left, when seen on the screen from behind, it will appear to bulge somewhat to the left at its uppermost part—an appearance that might easily be mistaken by a tyro for aneurysm. Oblique illumination of the chest from left to right should always be done if there is any question of aneurysm, as a posterior bulging of the aorta may be detected by this means when it is not noticeable from in front or behind.

The movement of the diaphragm on the two sides should also be observed ; owing to the opacity of the liver there will be deep shadow beneath the right arch of the diaphragm, which is usually about an inch higher than on the left side. Markedly deficient movement of the diaphragm on either side will be suggestive of pulmonary tuberculosis.

Pleuritic effusions will be noticeable from the dark shadow thrown by them, especially empyema.

THERAPEUTIC ACTION

Owing to their penetrative power, X-rays are more suitable than ordinary light rays for affecting the deeper parts of the skin and tissues. The prolonged action of the X-rays upon the skin leads to the production of an erythematous reaction, and if the process is carried further this becomes a dermatitis, which is very slow to heal. Still longer exposures cause the appearance of sloughs and ulcers, which are most resistant to treatment. The parts should be protected from the air, and lanoline applied. Even carcinoma of the tissues has been produced by the long-continued action of the rays upon an operator. Falling out of the hair, due to destruction of the hair follicles, is one effect of prolonged X-ray exposure, which is taken advantage of in the treatment of ringworm of the scalp by Sabouraud's method.

Lupus, rodent ulcer, and epitheliomata of the skin may be successfully treated by X-rays ; but as regards **malignant disease** it is far better to combine X-ray treatment with surgical treatment. If the growth is capable of removal, it should certainly be thoroughly removed, and X-ray treatment may be applied to the neighbourhood of the scar afterwards. If the growth is non-operable X-ray treatment may delay its progress, and appear to arrest or cure it for a time; but ultimate generalisation of the growth is likely to take place in the so-called cures. The pain and discharge may, however, be much relieved; and the treatment is certainly the best in non-operable malignant disease of the breast, or for widespread recurrence in the scar and glands. For internal cancer, such as carcinoma of the uterus, stomach, liver, etc., X-rays do not appear to be of any real service, except for allaying pain, though a case of cure has been published of inoperable cancer of the cervix of the uterus, by applying X-rays through a Ferguson's speculum.

Ringworm has been successfully treated by Sabouraud and others with X-rays. Sabouraud's method is to apply a sufficient dose of X-rays in a single sitting, so that the hair falls out after a few days. This he finds to be the maximum dose that the skin will stand without a severe dermatitis being set up. Focus tubes, fitted with metallic guard shields for concentrating the X-rays on the affected part of the scalp, are used. The tube is enclosed in an ebonite-lined iron cover, or lead glass shield, having an opening on the side of emergence of the X-rays. To this opening metallic cylinders or localisers of different diameters can be fitted, of such a length that the patient's head, when placed against their ends, will be 6 inches distant from the anti-kathode.

In order to know precisely how long to apply the X-rays a test indicator must be used—viz., a pastille of platinocyanide of barium, which must be held in the path of the X-rays, at a distance of 3 inches from the anti-kathode. These pastilles, of light yellow colour, turn brown under the action of the X-rays, and when they become the same colour as the standard tint supplied with the book of pastilles, the area of scalp has had a sufficient dose of the X-rays. The pastilles, when in use, must be protected by black paper from the action of ordinary light, which restores them to their original colour. This dose of X-rays is sometimes referred to as 5H (one unit), or 1H on the Holzknecht scale, being one-fifth of the maximum amount to which the skin may be subjected without producing dermatitis. By covering the area that has been treated with a sheet of lead cut to fit it, the whole affected area of the scalp can be treated at one sitting. After a fortnight the hair commences to fall out, the head becoming bald in a month, care being taken to pull out all the diseased hair. The head remains bald for two months, when a fresh downy growth of normal hair appears. From the first day of the treatment the scalp should be painted with a weak solution of tincture of iodine, 1 part to 9 parts of spirit. After the first fortnight, daily washings of the head with soap, and rubbing to get rid of the loosened hair, must be carried out.

The X-rays do not kill the fungus of the ringworm, but cause the hair to fall out—the diseased as well as the uninfected—the daily washings and rubbing of the hair completing the depilation. The action of the iodine solution is to prevent the infection of fresh areas of hair by the spores. This method of treatment requires great care and practice, but is very efficient. If the proper dose of X-rays is exceeded, the hair will either grow again badly, and crinkled, or it may not return at all. If it has not returned within six months, it will not grow again.

Favus is to be treated with X-rays precisely like tinea tonsurans, or ringworm, as just described. As with ringworm, the action of the rays does not kill the fungus, but produces depilation, and thus the removal of the infecting matter. Unlike ringworm, favus is more liable to involve the whole scalp.

Many other forms of skin disease have been treated with more or less success by X-rays, the more successful cases being obstinate chronic cases of **eczema.** The diseased patch of skin should be treated with a soft tube giving rays of about 4 on Benoist's radiochromometer, the dose of rays being 3H. This may be repeated every week. It must be remembered that the action of the X-rays is cumulative, so that a number of short exposures given daily may eventually set up severe dermatitis and ulceration. The effect of each exposure wears off in about three weeks, so that with exposures given with that interval the danger of cumulative action is practically nil.

Alopecia may sometimes be cured by X-rays when the scalp is covered with a fine downy growth. When the scalp has become completely bald and the skin shiny, the condition is quite hopeless. The result of the treatment is to cause all the downy growth to fall off after ten days or a fortnight, as in ringworm, the scalp becoming bald; but in the successful cases this is succeeded in from one to two months by a fresh crop of natural hair.

Cheloid, a curious condition of hypertrophic development in scar tissue, has many times been successfully treated by X-rays, the scar eventually becoming supple and much diminished in size.

Mycosis fungoides, an otherwise intractable and invariably fatal form of skin disease, associated with the development of nodular lumps in the skin, has several times been cured by patient and long-continued X-ray treatment. Daily treatment is given with soft rays of 4 or 5 degrees of penetration on the Benoist scale, the doses being as high as 7 to 10 H. The plan adopted is to limit the area of application of the rays by a localiser, and to attack different areas daily, no one area that has been so treated being again exposed to the rays until after twenty days, when it should again be treated as before. The limit of the skin reaction aimed at should be a slight erythema.

Nævus.—Extensive vascular nævi of the skin, or port-wine mark, may also be occasionally much benefited by this treatment. The dose of the rays, with a soft tube, must be pushed to the stage of strong reaction and desquamation, 7 to 9 H being required. The treatment is a very delicate one and somewhat dangerous to use, and should, therefore, be reserved for extensive spreading nævi which have already failed to benefit from electrolysis.

It has been proved over and over again that X-rays in moderate doses have a remarkable analgesic action upon the tissues, though in what precise way this is effected is unknown. This has been shown especially in the treatment of inoperable cancer by X-rays, in which, although the disease is scarcely, if ever, cured, yet the improvement of the patient due to the pain being much diminished or entirely arrested may be considerable. This analgesic action of the X-rays has been taken advantage of in the treatment of several other painful conditions, and it has been asserted that **hyperæsthesia** of the skin in tabes dorsalis, **intercostal neuralgia, post-herpetic neuralgia,** and even **trigeminal neuralgia** may be much improved, or even cured. For the latter, hard tubes, giving highly penetrating rays, are advised. Similarly **pruritus** may be treated by X-rays and the itching of the skin allayed or cured. In this affection the treatment should be reserved for severe and obstinate cases which have shown no improvement under careful regimen or treatment by high frequency currents.

Lymphoid organs were shown by Heinecke to undergo special modification, with destruction of lymphocytes, under exposure to X-rays. With this end in view, diseases affecting the lymph glands, such as lympho-sarcoma, lymphadenoma, and leukæmia have been frequently treated by this method. Of these, **leukæmia** seems most responsive to the treatment, and numerous cases of improvement or cure have been reported, both of the myelogenic and lymphatic varieties. Rays of moderate penetration must be used (Nos. 7 or 8 on Benoist's scale), the tube being held at 6 inches distant from the abdomen. With a large spleen it is recommended to divide the area over the spleen into four parts, and to treat one part each day, covering the others with lead sheeting. Each part should be exposed to the rays once a week, care being taken to provoke no dermatitis. The effect seems to be at first to produce an augmentation of the number of leucocytes, but after two or three days this increase is followed by a diminution in the numbers below the original. Any glandular enlargements should be exposed to the rays, and also the long bones of the limbs, especially their ends, as it has been shown that the leucocytosis depends upon an excessive proliferation of the leucocyte-forming matrix in the medulla of the bones. Owing to the density of the bones, hard tubes must be employed for this purpose, in order to provide rays sufficiently penetrating to reach the interior of the bones.

The red cells appear to undergo no alteration from exposure of the tissues to X-rays.

It has been shown that X-rays have a peculiar effect upon the testicle, setting up a condition of necrospermia, and leading ultimately to complete **azoöspermia** or sterility. For this reason X-ray operators should wear protecting aprons of heavy leather or rubber impregnated with lead. Many different forms of protecting apparatus are sold for the use of X-ray operators: lead-glass spectacles to protect the eyes, rubber gauntlets and aprons, etc., too numerous to specify here. Care should, however, be taken in treatment by X-rays or in X-ray photography to limit the field of action of the rays by means of localisers.

An **X-ray couch** is an essential for all operators who do much X-ray work. These are fitted with a carriage underneath for the tube, which may be enclosed in a lead-glass or rubber shield, or in a box of white-lead powder, or by similar means arranged to localise the beam of X-rays directly upwards to the patient. The carriage for the tube is also arranged on rails so that it can be placed underneath any required part of the patient. The lamp, too, should be moveable sideways for a distance of 3 inches, so that two photographs may be taken at that distance apart without moving the patient, in order to produce a stereoscopic picture. This was first done by Mackenzie Davidson, and the two negatives, after being developed, are mounted in a Wheatstone stereoscopic frame, the combined picture giving the appearance of depth which is altogether lacking in the single negative. By means of this principle, and using a localiser, the precise position of foreign bodies may be ascertained, such as particles of steel or glass in the eye or orbit, bullets in the chest or limbs, etc.

Stereoscopic pictures on the screen may also be arranged by means of a special X-ray tube with two anti-kathodes, and an arrangement by means of which the current is rapidly changed from one to the other several times a second, thus alternately emitting the beam of X-rays from two points about 2 inches apart. The same mechanism that rhythmically regulates the direction of the current must work a pair of shutters in front of the two anti-kathodes synchronously with the switching of the current to the anti-kathodes. The two pictures are never seen on the screen together at the same moment; but, owing to their very rapid alternation, they appear to the eye to become fused, and give the appearance of depth.

RADIUM

Soon after Röntgen happened on the X-rays through his experiments with Crookes tubes, Becquerel started investigations on the properties of uranium, and he was able to demonstrate that uranium and its salts are radio-active, and emit rays which are capable of acting on photographic plates, even though substances such as wood or paper be interposed. In this property the uranium rays, or Becquerel rays as they were named, resemble X-rays. Becquerel patiently investigated these uranium rays, and found that by the action of a strong electro-magnet he was able to split up the rays into three groups, one of which, like X-rays, is not acted on by magnetism, and two other groups, one of which is attracted by the north pole and the other by the south pole of the magnet. This fact of attraction of the two latter groups of rays by different poles of the magnet proves the rays to consist of positively and negatively electrified bodies. These three groups of uranium rays, or Becquerel rays, are usually called the alpha, beta, and gamma rays. The alpha rays consist of positively electrified particles, which have been proved to be about twice the size of hydrogen atoms; while the beta rays appear to be identical with the kathode rays, and consist of negatively electrified extremely minute particles, or electrons as Sir Oliver Lodge named them. The gamma rays are identical with X-rays.

This discovery by Becquerel of the radio-active property of uranium stimulated Madame Curie and her husband to work at the subject, and they selected for their labours the rare mineral, pitchblende, in which uranium is always found. By infinite labour and patience they succeeded in separating out a substance from the barium in the pitchblende, a metallic salt which in the form of chloride or bromide they found to be about one million times more radio-active than uranium. This substance appeared to be a metallic element, and it was named by them **radium**, and its atomic weight, according to Madame Curie's latest determinations, is 226.2. Two other radio-active metals which they also separated out in very minute quantity, were named actinium and polonium. Still another radio-active metallic element is thorium. This, like uranium and radium, has a very high atomic weight, uranium being the highest of all elements with 239, thorium next with 232, followed by radium with 226.2.

Study of the radium compounds, for the metallic element itself has never yet been isolated, has shown that radium salts emit rays precisely like the Becquerel rays from uranium, but infinitely more powerful. The beta rays from radium have a speed much greater even than that of the kathode rays of a Crookes tube, reaching the enormous rate of 150,000 miles per second, thus approaching the speed of light. These beta rays, by their impact upon the radium mass as they are ejected from the molecule, give rise to gamma rays, which are probably identical with X-rays. They have even greater powers of penetration through dense substances than the X-rays from a focus tube, being able to pass through more than twelve inches of solid iron. Radium is thus constantly giving out a steady stream of positive and of negatively electrified particles in the alpha and beta rays, due to the continual disruption, or detonation, of some of the radium atoms, and the radium mass must therefore be slowly diminishing in quantity. Owing to the continual discharge of this intra-atomic energy, the radium mass maintains itself at a temperature of 1° to 2° C. above that of surrounding objects. The rate of diminution is, nevertheless, comparatively slow, hundreds of years being required before the mass is appreciably diminished. It has been shown that the radium gives off an intensely radio-active substance, which has been called the radium emanation, and which in turn breaks down further, giving rise to helium and an emanation X. This process need not be traced further here, nor the mass of theory regarding the ultimate constitution of matter, to which the action of radium salts has given rise Suffice it to say, that the results of recent work by Rutherford, J. J. Thomson, Soddy, and others go to prove that the emission of rays by radium compounds is due to the breaking down of some of the radium atoms, and the consequent ejection from the atom of some of the constituent electrons which go to form it. From this point of view all matter and all the so-called elements are composed of atoms, each of which is built up of different numbers of electrons, or negatively electrified particles, surrounded by a spherical shell of positive electricity.

Contact with radium compounds has been found to confer the property of radio-activity upon surrounding objects, lasting several days. This is due to the deposition upon them of the radium emanation. It is noteworthy that the radio-active elements are those which have the highest atomic weights; that is to say, whose atoms contain the greatest number of electrons, and it is the slow atomic disintegration of radium which gives rise to the emission of the rays described above. The alpha rays consist of positively electrified particles about twice the size of hydrogen atoms; they are the same as the positively electrified particles given off from glowing metals, and appear to be identical with helium—an inert gas, having the low atomic weight of 4, first discovered by Lockyer in the solar spectrum, and since isolated from our atmosphere. Thus radium, one element, gives rise to another element, helium—a process amounting to a transmutation of the elements, such as the alchemists of old dreamed of.

Therapeutics.—Only minute quantities of radium are obtainable, and though experiments have been made on cancerous growths, the therapeutic effects appear to be due merely to the X-rays given off.

Note.—Actinium, like radium, is found in constant proportion in all minerals containing uranium, and both are doubtless disintegration products of uranium, the immediate forerunner of radium being called ionium. The disintegration period of uranium is more than a thousand million years, while the period of radium is probably about 2,000 years. Polonium has been shown to be a disintegration product of radium, with a period of 140 days, and it is identical with Radium G. Bragg has recently suggested that the gamma rays of radium, and probably also the X-rays, are not pulsatory vibrations in the ether, but corpuscular in character, consisting of uncharged particles or "neutral pairs," projected at a high velocity.

CHAPTER XIII

STATIC ELECTRICITY AND HIGH FREQUENCY CURRENTS

STATIC ELECTRICITY

THE word electricity is derived from the Greek word "electron," signifying amber. The fact has been known since ancient times that amber, when rubbed, attracts light bodies; but it was Dr. Gilbert, of Colchester, who extended this observation to numerous other bodies having a similar function, which he therefore named "electrics." Dr. William Gilbert, who was physician to Queen Elizabeth, and President of the Royal College of Physicians in the year 1600, published in that year, only three years before his death, his famous work, "De Magnete," * which laid the foundations of the future science of electricity.

The form of electricity produced by friction of glass, sulphur, or ebonite with silk, fur, etc., is now known as **static electricity.** The two substances rubbed together become oppositely electrified. Thus, a glass rod or plate, rubbed with a dry piece of silk, becomes positively electrified, the silk acquiring a negative charge. Similarly, electrified bodies repel one another, while a positively electrified body is attracted by one negatively electrified. This principle explains the action of the electroscope, the two gold leaves becoming similarly electrified, and repelling one another, when an electrified body is brought near it.

A charge of static electricity is always at a much higher voltage than is usual with faradic or galvanic currents, and the charge is consequently quickly dissipated from projecting points or rough surfaces into the air. The method of conduction of electricity at the high tension of static electricity differs somewhat from the low-tension currents of ordinary galvanic batteries or of dynamos. With the low-tension currents the electricity flows along the whole of the cross-section of the wire, so that a solid wire will conduct more galvanic current than a hollow wire of the same size, in proportion to its weight. When the voltage of the galvanic current or the alternating current of a dynamo is raised above 1,000 volts, it is found that the current tends to flow more on the surface of the conductor than in its centre, the so-called "skin effect." With the high-tension currents of static electricity, this effect is very much more pronounced, and the current flows practically only on the surface of a conductor. Thus a wooden ball coated with tinfoil can be charged with as much static electricity as a solid metal ball of the same size. Owing to the high tension of the current, the charge flows comparatively easily along substances such as wood or leather that are fairly good insulators for low-tension currents; and it is exceedingly difficult properly to insulate bodies highly charged with static electricity, dry varnished glass, ebonite, and rubber being among the best insulating materials.

---

* "De Magnete Magneticisque Corporibus et de Magno Magnete Tellure Physiologia Nova."

The original machines for manufacturing static or frictional electricity produced the current by friction of sulphur balls, glass plates, or cylinders by the hand or by silk pads covered with mercury amalgam. Ramsden's glass plate machine was the best of its kind for more than a hundred years.

The positive electricity produced on the glass plate as it revolved was collected by metal points attached to a brass rod, which acted as prime conductor. The Leyden jar was discovered by accident in 1745. It was Benjamin Franklin, in America, who first explained its action, and it was he also who, in 1752, invented the lightning conductor, and demonstrated the fact that the lightning flash and the spark from the Leyden jar or electrical machine were identical. On account of Franklin's pioneer work on static electricity, the medical treatment by this form of current is sometimes known as "franklinisation."

Following the friction machines came apparatus for producing electrification by induction, and the invention of the **electrophorus** by Volta in 1775. This apparatus consists of a cake of resin fixed on a metal stand, and another metal disc of similar size, fixed to a glass handle. To use it the resin is rubbed with silk, producing negative electrification on its surface; the metal disc is then lowered upon it, touched for a moment with the finger, and then lifted by the glass handle. The metal disc is now found to be positively electrified, and this process can be repeated indefinitely, until the negative charge on the surface of the resin has slowly become dissipated in the air, and requires renewing by rubbing.

Electrostatic influence machines, or **continuous electrophori,** were next invented, by Holtz in 1865, by Voss and others, and later by Wimshurst in this country. In France and England the Wimshurst machine is almost exclusively used, and the Holtz in America. The latter machine has the disadvantage of requiring an initial charge to be given it, usually by a smaller Voss or Wimshurst machine; the last is self-exciting, if the plates have metallic sectors, though the later machines without sectors are not self-exciting, and require to be touched with the finger on the edge of the plate as it is revolving.

The **Wimshurst machine** consists of two plates or more, in pairs, arranged on a central axle so that each pair of plates revolves in opposite directions (see Fig. 9, p. 35). In a machine with twelve plates, the second and third plates will be fixed on the same axle block and rotate together, the fourth and fifth similarly coupled together and rotating in the opposite direction, and so on, the outer plates at the two opposite ends rotating in the same direction if there is an even number of pairs of plates, and in reverse directions if the number of pairs is odd. Such an arrangement of twelve plates will be driven by seven bands, the alternate ones being crossed. In this country the plates are usually made of glass, the plates being ⅛ inch apart, and their diameter 24 to 30, or even 36 inches. Each pair of plates has two pairs of metallic brushes, whose tips graze the surface of the edges of the plates. Each pair of brushes is carried on a curved metal rod attached to a prolongation of the fixed axle. They should be so placed that, on facing the plate, the curved rod occupies the position of the hands of a clock pointing to five minutes to five. Curved metal collectors, with metallic points, surround each pair of plates, at the level of the horizontal diameter of the plates. The collector rod on each side is common for all the pairs of plates.

The voltage of the machine, that is to say, the length of the spark, depends on the diameter of the plates and the speed at which they are driven; while the output of the machine, that is to say, the frequency and the thickness and brilliancy of the sparks, depends on the number of plates and their speed of revolution. A machine has been constructed for the Science and Art Department at South Kensington, with plates 7 feet in diameter, which is supposed to give sparks 30 inches long, but no Leyden jars have been found to withstand the enormous electric strain. A large machine with eighty plates was built for Sir Archibald Campbell, which gives an enormous output. On account of the impossibility of rotating glass plates at high speed, owing to their liability to fracture, ebonite is often used, and very efficient machines, with twelve pairs of ebonite plates, of 22 inches diameter, are made. These can be safely rotated at the high speed of 1,000 revolutions per minute—twice as fast as with glass plates—and therefore the same voltage may be obtained with smaller plates. A dust-proof case is usually fitted to the larger glass-plate machines ; but it does not appear to be essential, though it certainly saves cleaning. Owing to the destructive effect of ozone upon ebonite, it is better not to enclose machines with ebonite plates in cases.

Machines for physical laboratories are fitted with Leyden jars, so as to increase the power of the spark, though the sparks will be less frequent. If the machine is being used to produce X-rays for photographic purposes, the Leyden jars should also be used, though they should be disconnected from the machine for most therapeutic applications. The larger machines, which are the only ones of use for treatment, with four or more pairs of plates, are best driven by an electric motor, of $\frac{1}{4}$ to $\frac{1}{2}$ horse-power.

In Pidgeon's influence machine there are nine revolving plates, consisting of three groups of three plates each. The three central plates 2, 5, and 8 are driven by the central axle in one direction, whilst the outer plates 1, 3, 4, 6, 7, 9 are carried on suitable sleeves and driven by bands in the opposite direction. The plates are made of volenite, with sunk metallic sectors, but a full description of the machine is unnecessary here. Like the Wimshurst machine with sectors, it is self-exciting, but its output is said to be about four times as great as that of the older form of Wimshurst.

A large Wimshurst machine, with eight plates of 30 inches diameter, when working well will give sparks of 6 to 10 inches in length. After it has been running for a few seconds, a glow of violet light appears upon the collecting brushes and points, and the speed of rotation of the plates becomes sensibly decreased, owing to the greater resistance from the self-induction of the machine. The current received from the collecting brushes by the fixed conductors is led to two brass knobs outside the case of the machine, which are separated by a distance of about 12 inches. The two poles of the machine should have adjustable sliding rods attached to them, ending in brass knobs, while midway between the poles is fixed vertically an ebonite rod carrying at each end a brass knob. The upper knob is attached to a metal chain connected with a gas or water pipe, while the lower knob is connected with a similar chain to connect it to the patient's circuit. The sliding rods attached to the discharging poles can be adjusted to be in contact with either the upper or lower knobs of the vertical rod between them, so that either pole may be quickly connected with the patient or with "earth."

The current supplied by a Wimshurst machine is unidirectional, and therefore one of the discharging knobs will be positive, and the other negative. In order to distinguish the two poles for the purposes of treatment, the following method, given by Lewis Jones, is useful. The machine is set in action, with neither of the poles connected to earth. A pointed electrode, connected by a light metal chain to earth, is then gradually brought near one of the two poles. If this is positive, a star of light will appear upon the point, even at a distance of several inches, and this star of light will remain without much alteration until the point is brought up almost into contact with the knob, when small sparks pass. If approached to the negative pole in the same way, the discharge takes the form of a visible brush or spark, when the point is still at a distance of 2 or 3 inches from the knob.

For the purposes of treatment, a strong **insulated stool** is necessary, and four or five different electrodes. The stool should be stoutly made, and should be fully 3 feet long by 2 feet wide. It should have a raised curved rim, to prevent the patient's chair slipping off the edge, and it should stand on four stout glass legs, 10 to 12 inches in length, and varnished. On the top of the stool should be fixed a zinc or brass plate, about 12 inches square, which is connected by a light metal rod with one pole, usually the positive. The patient sits with the feet placed upon the metal plate, and is thus brought in contact with the positive pole.

The **electrodes** that are necessary are four in number: (1) a metal ball or large knob on holder; (2) a metal roller, similarly mounted; (3) a multiple point electrode; and (4) a metal cap with multiple points, attached to a metal arm which can be swung out from the top of the case of the machine to hang over the patient's head. If the machine has no case, this electrode must be mounted on a tall stand, and connected to earth.

METHODS OF TREATMENT

There are four methods of treatment: (1) By sparks, (2) the breeze or effluve, (3) friction, (4) static charging.

With the ball or knob electrode, **sparks** are administered—a severe form of treatment which must be used with caution. Not more than one spark at a time is to be given, the electrode being rapidly approached and withdrawn before there is time for a second spark to leap across. The result of the spark is to cause a sudden spasmodic muscular contraction at the point of its application, and this mode of treatment may be used for muscular stimulation.

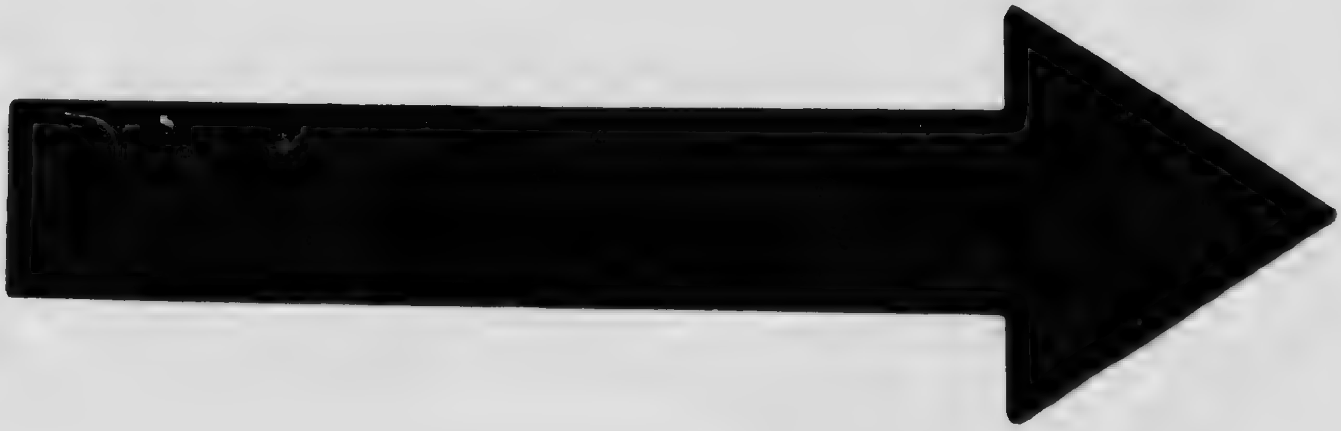
A better method for this purpose is to use Morton's "static induction." Leyden jars are then connected to the two poles of the machine, and their outer coatings are attached to connecting cords and ordinary pad electrodes, which are applied to the skin and muscles in the same way as with faradism. To control the intensity of the shocks, the sliding knobs attached to the two poles of the machine may be adjusted at variable distances; the nearer they are brought together the weaker will be the shocks from the outer coatings of the Leyden jars. This same method of adjustment of the sliding knobs is used to graduate the intensity of the sparks applied to the patient by the ball electrode, or instead, the operator may weaken them by putting his foot on to the stool, so as to cause some of the static charge to leak away.

Another method of applying the static sparks for muscular treatment is to avoid sparking the skin entirely, and to allow the spark to jump from the knob electrode to a small metal electrode held over the motor point on the skin by an insulated glass handle. In this way the skin escapes the powerful stimulating action of the spark, which often results in the appearance of large wheals, resembling urticaria, when strong sparks are taken from a small area of skin for several seconds together. The muscular contractions resulting from the stimulation of the spark can be produced in cases of nerve injury and degeneration, even after the muscles have lost their reaction to faradism. In the progress of the reaction of degeneration, the reactions to the static sparks disappear before the excitability to galvanism is lost.

The sensory stimulation by spark treatment is powerful, and may be of considerable use in hysterical anæsthesia and functional paralysis.

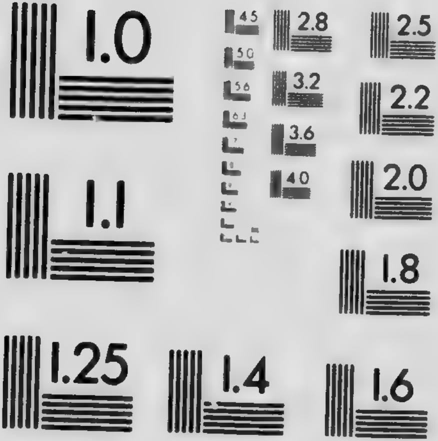
A milder, and in most cases better, way of obtaining the same form of sensory stimulation is to use **friction**. This is done with the metal roller electrode, which is rapidly rolled outside the patient's clothing, over the limbs, and especially along the spine. The thicker the clothing—and it must be dry—the stronger are the sparks which shower through on to the skin underneath, so that the additional thickness of a blanket, or other woollen garment, may be added when the treatment is required to be specially stimulating.

The breeze or **effluve** is administered by a single point or, better, a multiple-point electrode, which is connected to earth by a chain, while the patient sits on the



MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc
1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

insulated stool and the footplate connected to the positive pole of the machine in action. The point electrode is directed towards the patient, being gradually approached to the various areas that require treatment. It produces a wind, or souffle, which is felt as a cool breeze on the exposed parts, or as a hot pricking upon the parts covered with clothing. When administered in this way, the treatment is called the "negative breeze," because the patient is positively charged. The point electrode can, under these circumstances, be approached much nearer to the patient without a spark passing than when the footplate is attached to the negative pole and the positive pole is earthed. The treatment is very sedative, if given properly, and is a useful means of treating neurasthenic headache, and neuralgia of different forms, and the pains of neuritis. This form of static brush discharge is said to be very efficacious in the treatment of *chronic indolent ulcers.*

Static charging, or the static bath, is applied by placing the patient in a chair on the insulated stool, connecting the footplate to one of the poles of the machine, and setting it in motion. No electrodes are used. As the machine is kept running, the potential of the patient on the stool is raised to that of the prime conductors; he is thus placed in an electrostatic field, and the charge, being at a high potential, leaks away from his hair, limbs, and all prominences, to the surrounding air and neighbouring objects in contact with earth. As he loses his charge, so is it replaced by the continued working of the machine; his hair stands on end, his skin feels pricking, and the face cobwebby. Usually the patient is charged positively, the effects being more sedative of pain and exhilarating than when charged negatively.

This treatment by static electricity is said favourably to influence metabolism and respiratory exchange. The appetite improves, sleep returns, and depression of spirits tends to disappear. An effect that has been observed is raising of the blood-pressure, and this method of treatment is to be avoided in arterio-sclerosis and renal disease, and the form of headache associated with high blood pressure. Many subjects perspire profusely from the forehead and hands during the treatment. The treatment may be combined with the douche, by swinging the cap with metal points over the patient's head at a distance of six inches. When this is done, the positive charge rushes mainly to the head and leaves the scalp by the hair, which stands on end, as the current passes off in the effluve to the metal cap, which by being earthed is connected to the negative pole. This is the most useful form of static treatment for various forms of headache—more particularly the neurasthenic and neuralgic. Insomnia especially seems to be relieved by positive charging.

Treatment by sparks or friction with the roller will be indicated in cases of hysterical paraplegia and anæsthesia, and other functional paralyses, and it is sometimes most useful in lumbago and other forms of muscular rheumatism. The treatment should not, as a rule, be given strong enough or long enough to produce pain ; but the aim should be to administer a strong moral stimulus with a minimum of painful impression. The patient should, on no account, be allowed to play with the machine or to remain in the room when it is being used for any other purpose than his treatment. This is important, because the beneficial effect of the treatment in this class of case is obtained by producing an effect upon the mental condition, whereby the condition of auto-hypnosis or semi-voluntary, semi-involuntary inhibition of the motor and sensory centres by the highest centres of the brain, which constitutes hysteria, is relaxed. The treatment must, therefore, be applied always with due formality and impressiveness in cases of hysteria ; for should the patient by undue familiarity acquire a disrespect for the treatment, it will be certain to have little or no good result.

In addition to the various medical applications of static electricity, the Wimshurst machine may be used to excite an X-ray tube. A powerful machine is necessary, having not less than four pairs of plates, and good pictures on the screen may be obtained, the light being absolutely steady. The output of the machine does not compare, however, with that of a good coil, and a galvanometer in the secondary circuit will indicate only a small fraction of a milliampère passing through the tube. Hence, for photography or therapeutic applications, much longer exposures are required.

High-frequency effects also may be obtained from a good static machine by using Leyden jars, and connecting the outer coats through a stout coil of copper wire.

HIGH-FREQUENCY CURRENTS

To two men especially we owe the development of the medical applications of high frequency currents. D'Arsonval, in 1890, had repeated and extended Ward's experiments, which proved that with rapidly alternating electric stimuli, muscular excitation increases until the speed of the alternations reaches about 3,000 per second; as the speed is still further increased, the amount of muscular contraction progressively diminishes. Tesla in the early nineties, experimenting with oscillatory currents at high voltages, produced by Hertz's apparatus, found that currents powerful enough to light up incandescent lamps produced no appreciable effect upon the human body. Treatment by these currents is often called D'Arsonvalisation.

An oscillatory discharge, or high-frequency current, is produced by the discharge from the coats of a Leyden jar. The smaller the capacity of such a condenser, and the less the resistance of the circuit through which the discharge takes place, the more rapid will be the oscillations. If the discharging circuit has a high resistance, or high self-induction, the oscillations are less rapid, or the discharge becomes a continuous one. This phenomenon is usually compared to the sudden or slow emptying of a water reservoir. If two glass vessels, at the same level, are connected below by a wide tube, having a cross-section large in proportion to that of the glass vessels, then if one of the vessels is filled with water, and the tap be turned, allowing the water to rush from one to the other, the water will reach its level by a series of oscillations, whereas, if the tube connecting the vessels together is small, the water will slowly rise in the second vessel until its height is the same as that in the first vessel, without any oscillations.

If the spark of a Leyden jar discharge be made to pass through a piece of paper held between the two terminals, it will be found that the edges of the hole in the paper are turned up on both sides, which suggests that the sparks did not pass through the paper in a definite direction, but that the disruptive discharge was an oscillatory one. The duration of the spark is extremely brief, being calculated as less than the one hundred-millionth part of a second. The high-tension spark develops the greatest heat known, higher than the electric arc furnace, and comparable to that of the hottest known stars, such as those in the constellation of Argo. The spectrum of this spark resembles that of these stars in showing the lines of the proto-metals. Its duration is so brief that a flying rifle bullet, as it leaves the muzzle of the gun, may be sharply photographed by its illumination. The usual frequency of the oscillation in a high-frequency apparatus is said to be about 100,000 per second, though Hertz with his apparatus produced them at a speed of 50,000 million per second. These discharges set up oscillations in the ether which are known as Hertzian waves, and are made use of by the various systems of wireless telegraphy, waves up to 2½ miles in length being produced with the powerful coils employed.

It is instructive to compare the length of these waves with that of X-rays, which are produced by the action of a similar large induction coil in a Crookes tube. These latter rays are due to wave lengths, of which one hundred million occupy the space of only 1 inch, being 2,000 times shorter than the wave length of green light. Electro-magnetic waves, or Hertzian waves, may vary from one ten-thousandth of a millimetre to 12,000 feet in length, or even more, and their discovery has gone far to prove Clerk Maxwell's hypothesis of the electro-magnetic properties of light.

The number of oscillations at each Leyden jar discharge varies from ten to twenty, dying rapidly away ; and it is therefore necessary to keep the Leyden jars or condensers continually recharged, in order to obtain a steady supply of high-frequency currents. Any high potential source of electricity may be employed for this purpose, such as a static machine, or a large induction coil such as is used for the manufacture of X-rays ; or the alternating main current may be used, after passing it through a step-up transformer to raise the voltage of the current to 10,000 volts or more. The simplest apparatus is that described by D'Arsonval, in which the outer coatings of two Leyden jars or condensers are joined together by a helix of thick wire (see Fig. 10, p. 36). The terminals of the spark coil or static machine are attached by wires to the inner coatings of the two jars, and a spark gap is arranged between them inside a glass box, which acts as a silencer for the otherwise deafening noise of the spark. The wire of the primary coil or helix should be thick, and may be hollow, and need not be insulated further than by the air between the neighbouring coils. This coil, by its self-induction, acts like the primary coil of a faradic battery, though no iron core is required. So great is the resistance of this coil through its self-induction, that if the finger be held close to two turns of the coil when the machine is in action, sparks will jump across the air gap from each turn of wire to the finger, the current thus preferring the enormous resistance of this alternative path rather than traverse the coil of wire. Wires led off from the two terminals of this primary helix, or solenoid, will carry high-frequency currents, which can be used for application to the patient, who is thus placed in a shunt circuit with the condensers. The form of the oscillatory currents which traverse the patient's body is not known.

Instead of this form of primary solenoid, a more powerful apparatus may be used to produce high-frequency currents of higher voltage for the effluve, or even for spark treatment. The current from the outer coatings of the condensers is sent, instead, into a solenoid known as Oudin's resonator, or Tesla's transformer may be used.

Oudin's resonator consists of a helix of wire wound vertically on a wooden frame, ending at the top in a metallic knob (see Fig. 11, p. 40). The wires from the condensers are attached, one to the bottom of the helix, and the other through a movable clip to one of the coils of the helix, usually about one-quarter of the height of the helix from the bottom. The position of this clip has to be varied according to the use to which the resonator is put, in order to get the best effect, with the most powerful effluve; this is known as the tuning of the resonator. The part of the solenoid between the attachments of the wires from the condensers acts like the primary coil already described; while the upper portion of the solenoid acts as the resonator to the primary helix, increasing immensely its power. When in use, and the movable clip is adjusted to the best advantage, streams of violet light, or the effluve, issue from the knob on the top of the resonator. To this knob is attached the wire leading to the multiple point or other electrode used for administering the effluve, and a wire from the bottom of the solenoid is attached to a gas or water-pipe, to ensure an earth connection.

Tesla's transformer consists of a primary coil or helix of four turns of wire, which carries the current from the condensers, surrounding a secondary helix of a much larger number of turns of finer wire, wound on an ebonite cylinder, and separated from the primary helix by an air space of 1½ to 2 inches. This secondary helix can be pushed in or out of the primary, in order to vary the strength of the induced current. This machine acts just like the primary and secondary coils of a faradic battery, with the difference that in this transformer the secondary is inside the primary, instead of outside, and there is no iron core. To one of the terminals of the secondary coil is attached the wire to the multiple point or other electrode used for treatment, the remaining terminal being connected to earth, or to the metallic plate at the back of the condenser couch.

The condenser couch.—This is a long ordinary couch of bentwood and cane, covered with insulating cushions, and to the back is fastened a large metal plate, which is attached by a wire to one end of the primary solenoid or resonator. This couch is used for treatment by *auto-condensation.* The patient lies on the couch, and holds in one hand a metal handle, which is attached by another wire to the other extremity of the solenoid. A good plan is to earth the end which is attached to the back plate of the couch, as is done with the Oudin resonator and the Tesla transformer.

Large cage solenoid.—This is a large wire helix in the form of a cage big enough to enclose the patient when sitting on a chair. It is raised up and down by means of a pulley and counterpoise. The wire solenoid, like the primary coil, has very little ohmic resistance, but great self-induction. This method of treatment is called *auto-conduction.* The large solenoid takes the place of the primary helix, and currents are induced as a secondary circuit in the patient's body. To demonstrate the production of these induced currents, the patient should hold in one hand a Geissler vacuum tube, which will glow brightly while the apparatus is working. If, instead of a Geissler tube, he holds an incandescent electric lamp, with one of its attached wires in each hand, the arms being held parallel to the wires of the solenoid, the lamp will light up. In spite of the passage through the patient's tissues of such powerful currents as are evidenced by the lighting up of the lamp, the patient himself is conscious of no sensation.

Various electrodes are made use of in high-frequency treatment.

The **multiple point** electrode, for administering the effluve from the secondary solenoid or Oudin's resonator, is built on the same plan as that used with the static machine. An excellent form of this electrode is sold by Messrs. Gaiffe for use with their high-power alternating current high-frequency apparatus (see pp. 327–28). It differs from others in being burr-shaped, with the wire bristles set thick and close.

Metallic electrodes shaped like a cone and ending in a blunt point are used occasionally for administering strong sparks from the resonator or secondary coil. These sparks will be white sparks, not blue like those from the effluve, and they are painful and strongly stimulating. They are comparable to those from the metallic roller or metal point used with the static machine, and must not be directed continuously at any one point of the skin, or blisters will be raised.

Bare metal electrodes may be used in direct contact with the skin, as in the treatment by the condenser couch, when the patient holds a metal electrode in one hand, which is connected to one end of the primary coil. A metallic blunt-pointed cone-shaped electrode is also used in the treatment of hæmorrhoids and painful fissure of the anus.

Variously shaped glass **vacuum electrodes** are useful for the application of the current by administering blue sparks to the skin or mucous surfaces. An insulating handle with a binding screw attachment is fixed on to a hollow glass electrode of various shapes, usually more or less disc-shaped at the end. The hollow glass electrode is partially exhausted of air, and a wire projects into the vacuum, and is connected through the binding screw attachment to the primary or secondary solenoid. When the machine is in action, the interior of the glass electrode glows with violet light, and numerous fine crackling blue sparks will pass from the patient's skin to the outer surface of the glass, when this is rubbed over the surface. These currents are induced by the flow of electricity inside the conducting vacuum to the inner surface of the glass. Sometimes the glass becomes perforated by a spark, rendering the electrode useless. These blue sparks are not painful, like the white sparks from the single-point metal electrode, and they produce a stimulating effect upon the skin and a prickling sensation accompanied by a feeling of warmth, with dilatation of the superficial vessels.

A milliampèremeter should be used in the circuit when the patient is treated on the condenser couch, the instrument being placed in the circuit between the solenoid and the patient. The instruments register on the hot-wire principle, and currents of 100 to 500 ma., or even much more, may be used. With the method of autoconduction, when the patient is enclosed in the large cage solenoid, there is no method at present for registering the current passing through him.

MEDICAL APPLICATIONS OF HIGH-FREQUENCY CURRENTS

The general effect of treatment by high-frequency currents, whether applied by autoconduction, by the condenser couch, or by local applications of the effluve or sparks, is to cause a dilatation of the superficial blood vessels, with an increased volume of the capillary pulse, and a consequent fall in the general **blood pressure**, and raising of the surface temperature. The fall in the blood pressure may be quite considerable (according to Moutier, as much as 30 to 40 mm. of mercury at each sitting). My own observations with the Riva Rocci sphygmomanometer upon the brachial artery, immediately before and after treatment with the condenser couch method for twenty minutes, using the full strength of the primary coil of twenty turns of wire, of a powerful machine driven from a 10-inch coil, have frequently shown a drop of 10 to 12 mm. of mercury, when the pressure before the treatment ranged from 140 to 150 mm. The fall in pressure tends to become permanent, when the original pressure is greatly above the normal, though six or more treatments will be required. Moutier claims that the blood pressure can be permanently reduced to normal limits, even in cases of arterio-sclerosis, and he asserts that the effects in this direction are much more powerful with the method of autoconduction, using the large cage solenoid to enclose the patient, than with the condenser couch. Most observers report the effects of the two methods to be much the same.

This method deserves a more extended trial in the treatment of arterio-sclerosis and chronic renal disease, in which the blood pressure, as tested with the Riva Rocci instrument, frequently registers as much as 250 mm. of mercury, and even more. The bad effects of this high blood pressure, the headache, the tendency to cerebral hæmorrhage, etc., are so serious and so difficult to control with drugs and ordinary hygienic and therapeutic measures, that the high-frequency treatment deserves to be thoroughly tested.

Cases with abnormally **low blood pressure** have also been recorded as being improved, with raising of the blood pressure to normal, by condenser couch treatment. It is difficult to explain this apparent paradoxical result on physiological grounds.

Metabolic effects have been claimed for high-frequency treatment in gout, chronic rheumatism, obesity, diabetes, and other conditions of disordered metabolism; but I am not aware of any convincing records or experiments to prove these assertions. It is true that the experiments of D'Arsonval and others have shown that high-frequency treatment leads to accelerated respiratory exchange, with increase in the amount of the carbonic acid expired, and increased diaphoresis and diuresis; but I know of no definite proof of any marked increase in the nitrogenous excretion as a result of high-frequency treatment. Indeed, on reflection, we should scarcely expect to find chemical effects from treatment with high-frequency currents, as they are alternating currents, and their effects would probably be confined to stimulation of the tissues, as is the case with sinusoidal currents and faradism. On the other hand, the unidirectional currents—galvanism and static electricity—are capable of producing chemical effects with the transference of ions.

Certain **neuralgic states** may benefit by high-frequency treatment, especially neuralgic headache by the brush discharge, or by using the condenser couch method, and at the same time employing light massage with the tips of the fingers to the forehead and scalp. This method causes fine blue sparks to play from the scalp to the masseur's fingers, producing a sensation of tingling and warmth, which sometimes has a marked anodyne effect. Occasionally, after treatment on the condenser couch, marked hysterical phenomena are evoked, the patient complaining of inability to stand, giddiness, and faintness.

Hæmorrhoids and **painful fissure** of the anus may be beneficially treated by means of a blunt-pointed metallic cone electrode, or a similarly shaped vacuum glass electrode. The introduction of the instrument, which must be vaselined, will probably cause considerable tenesmus at first. As soon as the current is turned on, the muscular spasm is said to relax, and a sensation of warmth and slight pricking is produced. Numerous applications will probably be necessary.

Falling out of the hair and **alopecia** has been observed to benefit by high-frequency applications, either by the effluve from the multiple point and resonator to the scalp, or by means of friction with the vacuum glass electrode used with the primary coil. The growth of the hair is probably stimulated by the superficial vascularity induced by the treatment.

Certain **chronic skin diseases** may benefit considerably by high-frequency treatment with the brush discharge from the resonator, notably lupus, acne, and chronic eczema. In the treatment of lupus and chronic eczema the best form of application is by means of a vacuum glass electrode with disc-shaped end, attached to the resonator or secondary coil, and held close to the diseased skin so as to rain a steady shower of sparks upon it for some minutes. As a result, inflammatory reaction is produced, followed by cicatrisation.

Chilblains, dead fingers, and Raynaud's disease are best treated by means of the glass vacuum electrode on the condenser couch, administering a shower of blue sparks to the affected parts. Usually the full strength of the primary coil should be used, and the disc-shaped end of the glass electrode should be moved slowly over the surface of the fingers and hand, or the foot, so as to rain the blue sparks upon the skin from a distance of about one-eighth of an inch. This treatment should be given for fifteen minutes daily. Chilblains usually clear up rapidly under it. If the electrode is rested too long upon any part of the skin, the application becomes rather painful and a sense of burning is produced, and a patchy redness of the skin may persist for a day or two, due to scorching.

Rheumatoid arthritis may also be benefited by the same treatment, the joints becoming less painful and more freely movable after several days' treatment. These results are probably due to the hyperæmia of the extremities produced by the vaso-dilatation resulting from the general effects of the high-frequency currents and the local irritant effect of the sparking. Similar improvement may be seen as a result of the passive hyperæmia produced by the routine applications of a Bier's bandage to the limb.

In all applications of the effluve from the resonator, or of blue sparks from the vacuum electrode to the hands or head or neck, it is necessary that all metallic contacts with the parts should be removed, such as rings, hairpins, hatpins; or, if the scalp is to be treated, the hat should be removed, as with ladies the wire in the hatband may attract sparks and cause a shock to be felt across the forehead.

INDEX

A

Abdominal reflex, 65
Abductor paralysis, 214
Abscess, alveolar, 79
ACC, 122, 126
Accidental shock, 293
Accumulator charging, 114
Accumulators, 28, 105, 111, **113**
Acids, 169, 242
Acne, 7
Acupuncture, 172
Adaptor plug, 27
Adductor paralysis, 68
Adhesions, gallstones, 97
——, gastric ulcer, 97
——, periarticular, 151, **197**
——, pericolitis, 97
——, pleuritic, 79
Agoraphobia, 61
Alcoholic neuritis, 202, 221
—— poisoning, 102
Alcoholism, 61
Alkalies, 169, 242
Alkaloids, 239
Alopecia, 8, 345, 370
Alpha rays, 349, 351
Alternating current (*see* Current)
—— —— dynamo, 188
—— —— electro-magnet, 295, 307
—— —— motors, 285, 287
—— ——, periodicity of, 188
Aluminium cells, 295, 327
Amaurosis, 67
Amblyopia, 58, 67, 73
——, tobacco, 206
——, toxic, 206
Ampère, 108
Ampère-hour, 108
Amputation stump, 71
Amyotonia, 306
Amyotrophic lateral sclerosis, 218
Anæmia, 3, 7, 53, 257
Anæsthesia, 66, 268, 361
——, cerebral, 83
——, cocaine, 5
——, hysterical, 58, **66**, 71, 86, 207
——, local, 268
——, "stocking and glove," 67
——, ulnar, 193
Anæsthetic, 102
Analgesia, 86
Anelectrotonus, 124
Aneurysm, 249, 341
Angina pectoris, 78, 173
Anions, **237**, 241
Ankle-clonus, 64, 84
Ankle-jerk, 64
Anorexia, 68
Antikathode, 320
Antrum of Highmore, 79
Anuria, 69
AOC, 123, 125, 126
Aphasia, 215
——, hysterical, 68
Aphonia, 84, 212
——, hysterical, 67, **212**
Apostoli's galvanocausis, 248
Arc lamp, 81, 311-313
—— light, 172, 316
Argyll-Robertson pupil, 208
Arm-bath, 197, 227, **258**, 259
Armatures, 29, 30, 276, **278**
Arsenical neuritis, 221
Arterio-sclerosis, 78, 310, 361, **369**
Arthritis, rheumatic, 105
——, rheumatoid, 5, 78
Asthma, 78
Ataxic paraplegia, 84
Athetosis, 6
Atony, lower bowel, 300
Atrophies, chronic muscular, 136
Atrophy, arthritic, 50, 137, 140, **149**
—— of hand, 179
——, idiopathic muscular, 136
—— interossei, 145
——, muscular, 49, 140, 301
——, optic, 86, 205
——, peroneal, 303, 305
——, progressive muscular, 130, **137**, 140, 146, 218, 219, 223, 302
——, —— neuritic, 305
—— trapezius, 216, 218
——, Werdnig-Hoffmann, 306
Attitudinising, 70
Auto-condensation, 39, 366
Auto-conduction, 41, 366
Auto-inhibition, 72
Azoospermia, 347

B

Babinski, on hysteria, 66
Baldness, 8, 345, 370
Bandaging, tight, 132
Basedow's disease (*see* Graves's)
Baths, arm, 197, 227, **258**, 259
——, cabinet, 310, 313
——, electric light, 310

Baths, faradic, 47, 54, 61, 71
—, foot, 227, **258**, 301-303
—, four-cell, 31, 227, **258**, 302
—, galvanic, 27, 28, 121, 222, 223, 227, **251**, 257, 269, 270
—, hydro-electric, 227, **251**, 270, 313
—, porcelain, 256
—, proportionate current to patient, 251, **260**
—, radiant heat, 172, **310**
—, Schnée, 31, 172, 227, **258**, 302
—, sinusoidal, 292, 299, 300, **301**, 303, 306
Batteries, 111
—, combined, **23**, 25, 128, 229
—, faradic, 9-14
—, galvanic, 15-28, 105-107, 111, 170
—, Leclanché, 16, **105**
—, patient's, **15**, 170
—, re-charging, 115
—, secondary, 105, **113**, 252, 270
Bauer's focus tubes, 331
Beard, Dr., on neurasthenia, 54
Béclère coal-gas mercury break, 39, **322**
Becquerel rays, 348, 349
Bell's palsy, 80, 134, **153**-158
Benoist radiochromometer, 336
Beri-beri, 152, 221
Bernheim on hysteria, 72
Beta rays, 349, 350
Black marks caused by positive needle, 244
Bladder stimulation, 47
Blepharospasm, 81, 82
Blindness, hysterical, 74, **206**
— —, sudden onset, 84
Blood-pressure, 7, 361, **368**
Blue light, 318
—— sparks, 368-371
Bowel, faradism of, 97
Brachial neuritis, **172**-177, 202, 203
—— plexus lesions, **177**-182, 189, 194-195, 203
Brain, laceration of, 56
Breeze, static electric, 37, **359**
Bright's disease 78
Bronchitis, 78
Bronchocele, 87
Bulbar palsy, 212, 219
Burn, galvanic, 119
——, X-ray, 338

C

Cage, solenoid, 366
Carbon pole, 117
Carbon-iron electrode, 313
Carcinoma, gastric, 92
Cardiac failure, 102
Caries of spine, 78
Catalepsy, 64, 71, **104**
Cataphoresis, 169, 177, 203, **238**-240
Cataphoresis with cocaine, 5, 239, **245**
—— with main current, 270
Cataract, posterior polar, 311
Cautery, 112, 113
Cells, accumulator battery, 252
— arranged in parallel, 112
——, chromic acid, 112
— —, Daniell, 108
— —, Hellesen, dry, 9, 16, **107**
—, Leclanché, dry, 9, 16, **112**
— —, ——, wet, 106
—, Obach, dry, 9, 16, **107**
—, storage, 113
Cerebral anæsthesia, 83
— tumour, 205
Cervical rib, 179
Chabaud's focus tube, 333
Cheloid, 345
Chilblains, 5, 226, **228**, 371
Chlorosis, 53
Chorea, hysterical, 64
Choroiditis, 74
Chronic constipation, 96
— eczema, 313, 345, 371
— muscular rheumatism, 78, 257, 313
— nephritis, 310
— paraplegia, 85
— — renal disease, 78, 369
— sciatica, 164, **171**, 257, 310, 313
— skin diseases, 313, **345**, 371
—— ulcers, 318, 360
Chvostek's sign, 136
Clarke's magneto-electric machine, 276
Claustrophobia, 61
Clavus hystericus, 61, 67, 90
Closing current, 44, 324, **329**, 331
Cocaine, cataphoresis, 5, 239, **245**
— — drug habit, 61
Coils, induction (*see* Induction)
—, Lewis Jones's, 12
—, secondary, **43**-47, 292, 325, 366
—, sledge, **12**, 29-31, 270, **291**, 299
—, Spamer's, 11
Colour vision, 67, 73
Coma, 3, **102**
Combined batteries, **23**, 25, 128, 229
—— faradism and galvanism, 24, **127**, 146, 151, **186**, 229
—— sclerosis, 84
Commutator for direct current, 30, 276, **281**
— — —, de Watteville, 23, **128**, 187, 229
Concussion, 55
Condenser, 38, 108, 325, 362-365
— — couch, 366
Conjunctival reflex, 65
Conjunctivitis, 81, 82, 315
Constipation, 3, 96, 97, 300
Constriction of visual fields, 58, **74**, 206
Contact-breaker (*see* Interruptor)
Continuous current (*see* Current)
Contraction, tonic, 156

Contracture, primary, 59, 64, 132, **159**
——, late, 158, 162, 222, 301
Convulsions, hysterical, 67, 70, 71, **103**
Convulsive tic, **74**, 75, 82, 224
Cooper-Hewitt lamp, 314
Cord, inner, 189, **191**
——, posterior, 192
——, transverse lesion of, **49**, 50, 140, 181
Corpuscles (*see* Electrons)
Cough, spasmodic, 68
Coulomb, 108
Cranial nerves, 205
Crutch palsy, 130, **183**
Current, alternating, 28, 32, 44, 188, 270, **275**
——, carrying power of copper cable, 286
——, closing, 44, 329
—— collector, 17
—— curves, 13, 279
——, density of, 120, **121**, 167
——, diffusion of, 125
——, direct, 105
——, —— main, 25, **252**-257
——, DC main, dangers of, 253, **269**
——, earth, 30, 32, 253-257, 269-270, 292-293, 299
——, faradic, 8-14, 42-50
——, high-frequency, 265, 294 (*see also* High Frequency)
——, high-tension, alternating, 32, 272-273, **286**, 317, 327, 353
——, ——, direct, 288
——, induced, 38, **42**, 44, 292, 358, 366
——, Leduc, 262
——, oscillatory, 38, 362, 365
——, pulsating unidirectional, 6, 30, 276, 281, **282**, 283, **295**, 327
——, secondary, **43**-47, 53, 292, 366
——, sinusoidal, 5, 28, 151, 188, 275, **278**, 294
——, ——, constant, 30, 284
——, ——, four-phase, 281, **298**
——, ——, periodicity of, **278**, 294
——, ——, polyphase, 296
——, ——, single-phase, 32, **280**, 283, 294
——, ——, three-phase, 31, 96, 280, 283, 287, 297, **298**
——, ——, two-phase, 281, **297**
——, ——, undulatory, 278, **283**
Cyanide cataphoresis, 240
Cyanotic reaction, 50, **137**
Cynobex hebetis, 68
Cystoscope, 113

D

Dancing mania, 69
Dangers of main currents, 30, 32, 253-257, **268**-274, 292-293
Daniell cell, 108
D'Arsonval galvanometer, 17, 19, 27
—— transformer, 36, 40, 41, **364**
D'Arsonvalisation, 362
Dead-beat galvanometer, 19
Dead fingers, 5, 226, **371**
Deafness, galvanism in, 211
——, nerve, 159
Debility, 53-54
Decomposition of water, 241
Deep sensibility, 193
Degeneration, reaction of (*see* Reaction)
Dental neuralgia, 79
Depression, 7, 360
Derived circuit, 38, 43
De Watteville switch, **23**, 128
Diabetes, 7, 78
Diabetic neuritis, 221
Dilated stomach, 3, **91**, 100, 136
—— venules, 244
Diphtheria, facial palsy in, 159
Diphtheritic neuritis, 212, 221
Diplopia, 82, 84, 139
Direct current (*see* Current)
—— —— electromagnet, 308
—— —— (DC) motor, 29, 283, **285**
Discharge, oscillatory, 37, 362
Dislocation of spine, 150
Disseminated sclerosis, 6, **84**, 226
Double consciousness, 70
—— hemianopia, 74
Dry cells, 9, 16, **107**
Dynamo, alternating current (AC), 188, **278**, 298
——, direct current (DC), **281**, 288
Dyspnœa, hysterical, 69

E

Earth current, 30, 32, **253-257**, 269-270, 292-293, 299
Earthed poles, **253**, 255, 256
Ecchymosis, meningeal, 56
Echolalia, 225
Eczema, 7, 313, 345, 371
Efficient intensity of alternating current, 279
Effluve, **359**, 361, 365
Electric baths (*see* Baths)
—— burn, 272-273
—— shock, 268, **273**
—— sleep, 267
Electrical horse-power, 109
—— units, 107-109
Electricity, conduction of, **236**, 286, 353
——, negative, 319, 351, 360
——, positive, 351-353, 357, 360
——, static, 6, 34, **352**
Electrification, general, 53, 61, 251, 301, 360, 366
—— of railways, 274, 287-288
Electrodes, 21, 51, 119
——, brass roller, 37, 358 **359**
——, carbon-iron, 313

Electrodes, destructive action of, 242
——, facial, 21
——, flat pad, 21, 51, 166
——, indifferent, 51, 126
——, intra-gastric, **93**, 96, 100, 299
——, laryngeal, 213
——, multiple-point, 37, 358, **367**
——, rectal, 98
——, roller, 65, 96, 98, 201
——, testing, 51, 52, 123, 213
——, treatment, 51
——, vacuum, 367-368
——, wire-brush, **62**, 65, 71, 86
Electrolysis, 27, 120, **236**, 242, 244, 247
—— of skin, 118
Electrolytes, 107, **236**, 241
Electrolytic rectifier, 295, 327
Electro-magnetic waves, 364
Electro-magnets, AC, 33, 307
——, DC, 278, 308
Electro-motive force, EMF, 108
Electro-negative element, 117
Electrons, **319**, 335, 349, 351
Electrophorus, 1, 354
Electro-positive element, 117
Electroscope, 352
Electrotonus, 124
Epilation, 4, 246
Epilepsy, 72
——, laryngeal, 215
Erb's myopathy, 303, 304
—— paralysis, 177-180
Erythromelalgia, 228
"Ever-Ready," lamp, 115
Exophthalmic goitre, 87, 230
Extension, passive, 181
Extensors (*see* Muscles)

F

Facial massage, 162
—— muscle, nuclear origin, 160
—— neuralgia, 79
—— paralysis, 16, 48, 80, 133, 135, **153**, 158, 160, 162
————, double, 159
————, galvanism in, 161
————, infranuclear, 163
————, middle ear, 154
————, nerve-anastomosis, 216, 218
————, nuclear, 160, 163
————, supranuclear, 153, 163
—— spasm, **74**, 162
————, nerve-stretching, 162
Fallopian canal, 153, 158
Farad, 109
Faraday, induction coil, 42, 275
Faradic bath (*see* Bath)
—— current (*see* Current)
Faradimeter, 45
Faradism, intragastric, **93-96**, 100
—— and galvanism, combined, 24, 79, 95, **127**, 146, 151, 186, 201, 229
Fatal shocks 253, 271, **273**
Favus, 344
Fibroids, electrolysis in, 248
Fibrositis, rheumatic, 78
Fifth cervical nerve, 177
—— cranial nerve, 209
Fillet, 83
Finsen light, 311
Finsen-Reyn lamp, 312
First dorsal root, 191, **192**
Flame arc, 316, 317
Fluorescent screen, 338
Focus tube, 320, 331-333
Fracture-dislocation, spine, 150, 181
Franklin, Benjamin, 353
Franklinisation, 354
Fraud in hysteria, 72, **207**
Frenkel's exercises, 87
Functional paralysis, 49, 65
—— spasm, 75
—— symptoms, 63

G

Gaiffe, high-frequency apparatus, 41
——, interrupteur autonome, 327
——, multiple-point electrode, 367
——, spring metal tapes, 333
Galvanic batteries, 17
—— current, 105
Galvanism, 4, 15, 105
—— and faradism combined (*see* Faradism)
——, effects on muscle, 122
——, —— on skin, 118
——, for deafness, 211
——, hydro-electric bath, 313
——, hyperexcitability to, 130, 132, 134
——, in brachial neuritis, 176
——, in facial paralysis, 161
——, in optic atrophy, 205
——, in sciatica, 166
——, rapid interruptions, 263
——, —— reversals, 265
Galvano-faradisation (*see* Faradism and Galvanism)
Galvanometer, d'Arsonval, 17, 19, 27
——, Schulmeister's floating, 20
Gamma rays, 334, 349
General electrification, 53, 61
—— paralysis of insane, 208
Globus hystericus, 67
Gastrectasis, 91
Gastric atony and dilatation, 91, 299
—— carcinoma, 92
Gastroptosis, 95
Geniculate ganglion, 154, 160
Gout, 7, 78, 152, 310
——, rheumatic, 238
Gouty eczema, 313
—— neuritis, 200
Gowers, on facial spasm, 75

Gramme ring, 282
Graves's disease, 69, 87, **230**, 257
—— ——, electrical resistance in, 234
Gummatous meningitis, 208
Gundelach's focus tube, 331

H

Habit spasm, 224
Hæmatemesis, false, 68
Hæmorrhoids, 370
Hand, atrophy of, 179
Hard tube, 331, 33
Head injuries, 55
Headache, functional, 4, 7, 67, 89
——, neuralgic, 89, 361, 370
——, neurasthenic, 7, 60, **89**, 361
Heart failure, 272
Helium, 350, 351
Helix, 38, 364-366
Hellesen dry cell, 9, 16, 107
Hemianæsthesia, hysterical, 58, 66, 207
——, organic, 84, 160
Hemianopia, 74, 207
——, double, 74
Hemiplegia, 6, 49, **83**, 137, 140, **150**, 160, 301
——, hysterical, 58, **63**
——, infantile, 223
——, muscular wasting in, 150
Herpes zoster, 235, **346**
Hertzian waves, 363, 364
Hiccough, 69
High blood pressure, 361, **369**
High-frequency currents, 7, 35, 37, 230, 265, 294, 328, **362**
High-tension currents (*see* Current)
—— shocks, 272
Hip, hysterical, 67
Holtz static machine, 354
Holtzknecht's pastilles, 337
—— scale, 344
Hot-wire milliampèremeter, 30, 41, 368
Hydrocephalus, 205
Hyperacusis, auditory, 154
Hyperæsthesia, 66, 67, 346
Hyperchlorhydria, 92
Hyperexcitability of muscle, 80, **130**, 132, 134
—— of nerve, 48, **131**
Hyperpyrexia, 70
Hypertrophic neuritis, 305
Hypnotic state, 72
Hypoglossal nerve, 216, **218**
Hypothenar muscles, 190
Hypotonia, 306
Hysteria, **62-74**, 85, 225
——, definition of, 361
——, pathology of, 72
Hysterical joint, 63, 67
—— visual fields, 67, 74
Hystero-genetic zone, 67

I

Incandescent lamp, 109-110, 113, 290, 294, 310-311, 317
Incontinence, 58, 84
Inco-ordination of arms, 85
Induction coils, **42-52**, 309, 321, 364
Infantile hemiplegia, 223
——, paralysis, 5, 49, 130, 133, 140, **141**, 223
Infranuclear lesion, 160, 163
Infraspinatus, 178-182, 303
Inner cord lesions, 191
Insanity, 70, 72
Insomnia, 7, **60**, 95, 361
Insular sclerosis (*see* Disseminated sclerosis)
Intensifying screen, 338
Internal resistance, 16, **110-112**, 116
Interossei, 52, 145, **189-194**
Interrupteur autonome, 322, 327
Interruptions, speed of, 24, 324, 326
Interruptor, electrolytical, 325
——, Mackenzie-Davidson, 322
——, mercury turbine, 322-324, 327
——, spring, **9**, **10**, 42-43, 187, 292, 321
——, slow, 24, **101-102**, 187, 211
Intestines, ballooning of, 69
Intragastric faradism (*see* Faradism)
Intrinsic hand muscles, 179, 190, 305
Iodine, in cataphoresis, 238, 241
Ions, salicyl, 169
——, theory of, 236-242
——, zinc, 239
Iron core, 10-14, 44-47, 291, 295, 324
Ischæmic myositis, 131, 132, 140, 197, **199**

J

Joint, hysterical, 63, 67
—— lesions, 149
—— —— in hemiplegia, 151
—— —— in neuritis, **174**, 197
——, tubercular, 149

K

Katelectrotonus, 24, **124**, 127
Kathode rays, **319**, 320, **334**, 350
Kations, **237**, 241
KCC, **122-123**, 125, 126, 130-137
Kilowatt, **109**, 228
Kienböck's quantimeter, 337
Klumpke paralysis, 179
Knee-jerk, 64, 306
KOC, **122**, **123**, 125, 126, 136

L

Labile method, 4
Lachrymal obstruction, 248
Landouzy - Dejerine myopathy, 303, **304**

Laryngeal crisis, 215
—— epilepsy, 215
—— paralysis, 212-214
—— vertigo, 215
Late rigidity, 49, 84, **301**
Lateral sclerosis, 84, 137
Lead neuritis, 135, 145, 183, 221
—— poisoning, 145-146
Leclanché cells (*see* Cells)
Leduc, cataphoresis experiment, 239
—— current, 202
—— motor, 263, 300
Lenard rays, **319**, 334
Lenz's law, 275
Leucocythæmia, 88, **234**, 346
Leucocytosis, 89
Leyden jar, 38, 108
Lewis Jones's battery, 12
Lightning pains, 87, 164
Lines of force, 44, 125
Lithium salts, 238
Live wires, 268, 272
Long line transmissions, 273, 287-288
Low blood pressure, 369
—— voltage main currents, 269
Lumbago, **78**, 148, 164, 257, 313
Lumbrical muscles, 190, 195
Lupus, 7, 312, 342, 371
Lymphadenoma, 238

M

Magnetic field, 42, 44, 726, 278, 308
Magnetism, 275, 308
Magneto-therapy, 33, 307-308
Main current (*see* Current)
Malingering, 57-59, 72-73
Malnutrition, 53
Manganese peroxide, 107
Massage, 171, 177, 201
——, facial, 162
——, with passive movements, 151, 171
——, Swedish, 77, 177, 202
Mastoid, operation on, 154, 157-158
Matter, electrical constitution of, 350
Maximum effect of battery, 112
Median nerve, inner head, 191, 195
—— ——, outer head, 195
Meningeal ecchymoses, 56
Meningitis, 212, 158, 205
——, gummatous, 148, 152, 208
——, posterior basic, 159
Mercury vapour lamp, **314**, 317
Metabolism, 53, 62, 369
Metallic filament lamps, 110, 317
Metronome reverser, **143**, 147, 187, 303
Microfarad, 108
Middle-ear disease, 157
Migratory neuritis, 203
Milliampère, 108
Milliampèremeter, hot-wire, 30, 41, **368**
Mimicry, 75
Moles, 246
Monoplegia, hysterical, 63
Moore light, 316-317
Morphia habit, 61, 166
Morton's static induced current, 37, 358
Motor, alternating current (AC), 285
——, direct current (DC), 29, **283-285**
——, Leduc, 6, **263**, 300
Motor-generator, 105, **284**, 287, 289
Motor-magnetic break, 322
—— points, **50**, 122
—— power, return of, 194
Motor-transformer, 28, 29, **284**, 293, 300
Muller focus tubes, 333
Multiple neuritis, 130, 202, **221**
Muscle, abductor laryngeal, 214
——, —— pollicis, 190
——, adductor laryngeal, 212
——, —— pollicis, 190
——, biceps, 178, 181
—— brachialis anticus, 178
——, ciliary, 208
——, deltoid, 149, 178, **181**
——, digastric, 209
——, extensor indicis, 192
——, —— longus digitorum, 200
——, —— —— hallucis, 201
——, —— minimi digiti, 192
——, —— ossis metacarpi pollicis, 183
——, —— primi internodii pollicis, 183
——, —— secundi internodii pollicis, 192
——, ——, radial of wrist, 145, 178
——, ——, ulnar of wrist, 145
——, extensors of fingers and thumb, 145, 192
——, flexor brevis pollicis, 190
——, —— carpi radialis, 195
——, —— —— ulnaris, 189
——, —— longus pollicis, 195
——, —— profundus digitorum, 189, 195
——, —— sublimis digitorum, 195
——, gastrocnemius, 142, 303
——, gluteus, 149, 303
——, hypothenar, 190
——, inferior oblique, 208
——, infraspinatus, 178-182, 303
——, interossei, 52, 145, **189-194**
——, intrinsic hand, 145, 179, 305
——, latissimus, 303
——, levator anguli scapulæ, 182
——, —— palpebræ, 208
——, lumbricals, 190, 195
——, masseter, 209
——, mylo-hyoid, 209
——, opponens pollicis, 190

Muscle, orbicularis oris, 153, 219
——, —— palpebrarum, 153, 160, 304
——, palmaris longus, 195
——, pectoral, 191, 303
——, ——, clavicular, 181
——, peronei, 201
——, pronator radii teres, 178, 195
——, quadriceps cruris, 304
——, reaction of degeneration, 129
——, recti, of eye, 208
——, rhomboids, 182, 217
——, scalene, 177, 182
——, serratus magnus, **182**, 304
——, splenius, 225
——, stapedius, 154
——, sterno-mastoid, 215-218, 225
——, supinator longus, 178, 183
——, supraspinatus, 178, 181
——, temporal, 209
——, tensor tympani, 209
——, tibialis anticus, 200, 305
——, of tongue, 218
——, trachelo-mastoid, 225
——, trapezius, **215**, 225, 304
——, triceps, 183
——, zygomatici, 161, 162
Muscular dystrophy, 137, **303**
—— rheumatism, 3, 78, 257
Musculo-spiral paralysis, 183
Mutism, hysterical, 68, 214
Myalgia, 78
Myasthenia gravis, 82, **138**, 209, 214, 219
Myasthenic reaction, 137-139
Myatonia (*see* Amyotonia)
Mycosis fungoides, 345
Myelitis, 6, 84, 137, 151, 216
Myopathy, 131, 137, 140, **303**
Myositis, ischæmic, 131, 132, 140, 197, **199**
Myotonia congenita, 305

N

Nævus, 4, 242, 244, 346
Needle-holder, 243-244
Needle, insulated, 243
——, negative, 243, 244
——, platinum, 249
——, positive, 244, 246
——, steel, 244
Negative breeze, 360
—— electricity, 319, 351, 352
—— element, 106, 117
—— phase, 28, 294
Nernst lamp, 316-317
Nerve-anastomosis, 216, 218
Nerve, auditory, 211
——, chorda tympani, 80, 154, 160
——, circumflex, 179
——, compression of, 196
——, cranial, 205
——, divided, 180
——, eighth cervical, 179, 191
——, external popliteal, 200
Nerve, facial, 153
——, fifth cervical, 177
——, —— cranial, 209
——, first dorsal, 179, 192
——, fourth cranial, 207
——, glosso-pharyngeal, 212
——, great occipital, 77
——, hyperexcitability, 48, 81, **131**
——, hypoglossal, 163, 216, **218**
——, injuries, 178, 183, 188, 195, 200
——, inner cord, 191
——, internal anterior thoracic, 191
——, long thoracic, 182
——, median, 194
——, musculo-spiral, 183
——, optic, 205
——, pelvic, 98
——, phrenic, 102
——, posterior scapular, 182
——, radial, 184-185
——, reaction of, 48, 131
——, —— of degeneration of, 81, 129, **131**
——, recurrent laryngeal, 214
——, regeneration of, 197
——, sixth cervical, 178
——, —— nucleus, 160
——, spinal accessory, 163, **211**, 216
——, stretching, 162, 172
——, suprascapular, 179
——, third cranial, 208
——, trigeminal, 77, **209**
——, ulnar, 188
——, vagus, 211-216
Neuralgia, **76**, 177, 239, 307, 346, 360
——, dental, 79
——, facial, 79, 211
——, sciatic, 77, 164, 171
——, trigeminal, 5, 210
Neurasthenia, 7, 54-62
——, traumatic, 55
Neurasthenic headache, **89**, 360
Neuritis, 78, **80**, 145, **152**, 310
——, alcoholic, 159, 202
——, arsenical, 221
——, brachial, 5, **172**, 202, 203
——, degenerative, 153
——, diabetic, 221
——, diphtheritic, 212
—— of feet, 202
——, gouty, 173, 200
——, gummatous, 148
——, hypertrophic, 305
——, inflammatory, 158
——, influenzal, 173
——, interstitial, 153
——, joint changes in, 174
——, lead, 135, 145, **183**, 221
——, local, 152
——, migratory, 203
——, multiple, 130, 152, 158, 202, **221**, 257
——, optic, 205
——, peripheral, 152, 164, 301

Neuritis, peroneal, 200
, post-diphtheritic, 221
, retro-bulbar, 206
, rheumatic, 200, 238
, sciatic, 76, 164
, traumatic, 179
, trophic changes in, 174
, tubercular, 202
, ulnar, 190
Neuroma, 71
"Neuron," The, 295, 307
Neurone, lower motor, 133, 140
—, upper motor, 140, 150
Neurosis, 72
Neurotic tachycardia, 70
Night terrors, 60
Nodon valve, 2, 6, **295**
Nuclear lesion, facial, 163
Nucleus ambiguus, 212
Nystagmus, 85

O

Obach dry cell, 9, 16, **107**
Obstetrical paralysis, 177
Occluded gases, 331, 335
Occupation neuroses, 222
Ocular paralyses, 84, **207**
Ohm, 16, **108**, 168
Ohm's law, 110
Open arc, 317
Opium poisoning, 102, 103
Optic atrophy, 86, 205
— neuritis, 205
Orthodiagraph, 339
Oscillatory currents, 38, 362, 365
Oscillograph, 279
Osmo-regulator, 330, **331**, 337
Osram lamp, 110, 317
Osteo-arthritis, 149
Oudin's resonator, 39, 40, 328, **365**
Ovarian tenderness, 66
Ozone, 308

P

Pachymeningitis, 165, 216
Palate, soft, 211
Palpitation, 69
Paralysis, alcoholic, 184
— of cervical sympathetic, 192
— of conjugate movements of eyes, 160
——, nuclear, 160
—, periodic, 306
—, post-anæsthetic, 183, 188, 20
—, spastic, 137, 302
, Sunday, 183
Paraplegia, ataxic, 84
, chronic, 85
, flaccid, 151
, hysterical, **63-65**, 361
—, spastic, 49, 64, 302
Passive hyperæmia, 372
Pastilles, Holtzknecht, 337
—, platino-cyanide of barium, 343
—, Sabouraud's, 337
Patient's battery, 15
Peptic ulcer, 92
Perineuritis, 155, 164
Periodic paralysis, 306
Periodicity, 294
Peripheral neuritis, 301
Peristalsis, 91
Peritonitis, hysterical, 67
Peroneal atrophy, 303-305
Pflüger, on electrotonus, 125
Phantom tumour, 67
Phosphorescence, 319, 320, 331
Photophobia, 81
Pidgeon's static machine, 356
Pin-point fields, 206
Pitchblende, 349
Plantar reflex, 65
—— ——, extensor, 65, 84, 85
—— ——, flexor, 65
Platinoid wire, 26
Platysma, 133
Pleurisy, 3, 79
Pleuritic effusion, 342
Pohl's commutator, 144
Polarisation, 106, 112
Polarity, 37, 117, 357
Poles, positive and negative, 117, 127-129
Polioencephalitis, 160
Poliomyelitis, acute, 49, 140, **141**
——, chronic, 136, 140
——, subacute, 140, 144
Polyarthritis, 310
Polyphase currents, 296
Positive electricity, 352-353
—— phase, 28, **294**
Post-diphtheritic neuritis, 221
Post-influenzal debility, 54
Posterior cord, 192
—— spinal roots, **149**, 204
Potassium iodide, 241
Pressure sensations, 193
Primary faradic current, 43
—— solenoid, 38, 365
Progressive muscular atrophy, 219, 223, **302**, **305**, **306**
Prolapse, rectal, 4, 100
——, uterine, 4, 101
Proportion of current in bath, 251, 260
Pruritus, 7, 346
Pseudo-hypertrophic muscular atrophy, 303
Pseudo-tabes, 221
Pseudo-writer's cramp, 224
Ptosis, 82, 139
Pupil-dilator fibres, 192
Pupil, paralytic dilatation of, 82
Pupils, Argyll-Robertson, 208
Pyloric obstruction, 92
Pyrexia, 70
Pyrolusite, 107
Psychical symptoms in hysteria, 70

Q

Quantimeter, Kienböck's, 337
Quartz lamp, 316
Quinine, in neuralgia, 79

R

Radiant heat, 87, 310
Radio-active substances, 349-350
Radiochromometer, 336
Radium, 334, **348**
Ramsden's static machine, 353
Raynaud's disease, 4, **226**, 257, 371
Reaction, cyanotic, 50, **137**
—— of degeneration, 48, 80, **129**, 134, 184-185
—— —— —— in nerve, 48, 81, **131**
—— —— ——, partial, 80, **134**, **135**, 154, 196
——, myasthenic, 137-139
Re-charging dry cells, 115
Red light, 317
Reflexes, 64
——, extensor plantar, 84, 85, 151
——, flexor plantar, 65
——, pupil, 70, 192, 208
——, superficial, 65
Regeneration of nerve, 197
Renal disease, 361, 369
Respiratory failure, 102, 272
Resistance of bath, 251, 260
Resistances, 13, 26, 252, 300
——, internal, 16, **112**, 113
—— of skin, **16**, 168, 234
Retinal stimulation, 206, 264, 267
Retro-collic spasm, 225
Rheumatic fibrositis, 78, 164
—— gout, 238
—— neuritis, 200, 238
Rheumatism, 7, 152
——, chronic, 78, 369
——, muscular, 3, 78, 257
Rheumatoid arthritis, 5, 78, 371
Rickets, 3, 53, 135
Rigidity in hysteria, 64
——, late, 49, 84, 151
Rings, slip, 29, 30, 280, 284, 297
Ringworm, 343
Rodent ulcer, 239, 313
Röntgen rays, 312 (*see also* X-ray)
Rotary converter, 284
—— transformer, 289

S

Sabouraud's method, 343
—— pastilles, 337
Salicylate of soda, 169, 241
Salicylic acid ions, 238
Schnée bath, 31, 172, 227, **258**, 302
Schulmeister's galvanometer, 20
Sciatica, 27, 76, **164**-172, 257, 310, 313
Sciatica, faradism in, 77
——, galvanism in, 166
——, neuralgia, 77
Sclerosis, amyotrophic lateral, 218
——, combined, 84, 302
——, disseminated, 6, **84**, 301
——, insular, 86
——, lateral, 84, 137, 302
Secondary batteries (*see* Batteries)
Secondary coil (*see* Coils)
Self-induction, 43, **110**, 325, 326, 331, 362, 364
Sensation, forms of, 193-194
Sense, stereognostic, 83
Senses, special, 58, **67**
Sensory crossway, 83
—— symptoms in hysteria, 66
Septicæmic neuritis, 221
Series-wound motor, 285
Shocks, 28, 170, 253, 268-274, 372
——, single faradic, 24, 52, 127
Shunt, 19
—— circuit, 26
—— rheostat, **26**, 27, 252, 291
Sigmoidoscope, 113
Sine curve, 28, 275, **278-280**
Single-phase (*see* Current)
Sinus, frontal, 79
Sinusoidal current (*see* Current)
Skin effect, 38, 110, 353
——, glossy, 174, 197, 202
——, resistance of, **16**, 168, 234
Sledge coils (*see* Coils)
—— transformer, 28, 30, 32, **291**, 299
Sleep, electric, 267
—— paralysis, 130, **183**, 191, 195
—— walking, 70
Slip rings (*see* Rings)
—— tube, 11, 14
Snow-blindness, 81, 315
Soft tube, 331, 332, 336
Solenoid, 19, 38, 44
——, large cage, 366
——, primary, 38, 365
Spamer's faradic coil, 11
Spark coil, **321**, 329, 364
Spark-gap, 39, 330
Sparks, 37, 72, 358-359, 361
——, blue, 368-371
——, high tension, 363
——, white, 368
Spasm, adductor, 84
——, extensor, 84
——, facial, **74**, 162
——, hysterical, 64, 75
——, orbicularis, 75
——, retro-collic, 225
Spasmodic cough, 68
—— torticollis, 5, 64, 76, 216, **224**, 230
Spastic paraplegia, 49, 64, 137, 301, **302**
—— rigidity, 150
Spasticity, 84
Speech, scanning, 85

Sphincters, incontinence of, 58, 84
Spider nævi, 244
Spinal syphilis, 148
—— tumour, 78
Spintermeter, 337
Spleen, enlarged, 88, 234, 347
Splenic anæmia, 234
Splint, pressure from, 132
Sprengel shoulder, 218
Spring contact, **26**, 254, 302
Stabile galvanism, 4
Static charging, 360
—— induction, 37, 358
—— machines, 34, 328, 353-357
—— ——, output of, 356, 362
—— transformer, **32**, 270, 287, 289
Step-up transformer, 41, 287, 290, 327
Steppage gait, 200
Sterility, 347
Stigmata, hysterical, 55, 207
Stomach, dilated, 3, **91**, 100, 136
Strabismus, 82, 208
Strictures, 248
Strychnine ions, 240
Suggestion, treatment by, 73, 74, 91
Superfluous hairs, 246
Supranuclear lesion, 163
Suture, secondary, 193
Switchboard, 25, 272
Syncope, 3, 102, 273
Synchronous motors, 286
Syphilis, 148, 159, 200, 205, 208, 210
Syringomyelia, 212, 219, 223

T

Tabes dorsalis, 78, **86**, 205, 208, 226
Tabetic pains, 87, 164
Tachycardia, **69**, 70, 88, 230, 233, 257
Tantalum focus tubes, 333
—— lamp, 110, 317
Taste, loss of, 154, 157, 160
Teeth, carious, 81
Telephone wires, live, 271
Tesla transformer, 38, 365
Tetanus, from DC main, 124
——, anodal and kathodal, 130
Tetany, 135-136
Third rail, 124, **271**, 287
Thomsen's disease, 305
Three-phase current (*see* Current)
Three-wire system, 256
Thury system, 288
Thyroid gland, 87, **230-233**
Tic, convulsive, **74-76**, 82, 224
—— douloureux, 75, 79
Tinnitus, 211
Tobacco amblyopia, 206
Torticollis (*see* Spasmodic)
Toxæmic headache, 310
Toxic amblyopia, 206
Transformers (*see* D'Arsonval, Sledge, Static, Step-up, Tesla)
Transverse lesion of cord, 49, 50, 140
Traumatic neurasthenia, 55-60
Tremors, intention, 85
Trigeminal neuralgia, 5, 77, **210**
Trolley wire, 124, 271
Trophic changes, 197
Trousseau's sign, 136
Tubercular joint, 149
—— lung, X-ray, 341
—— neuritis, 202
Tumours, cerebellar, 158
——, cerebral, 159, 205
—— of medulla, 219
——, pelvic, 164
——, phantom, 67
——, pontine, 158
——, spinal, 78, 165

U

Ulcers, 7, 119, 318, 360
——, corneal, 81
——, peptic, 92
——, rodent, 239
——, X-ray, 338
Ulnar anæsthesia, 193
—— nerve paralysis, 188, 192
—— neuritis, 190
Ultra-violet rays, **310-316**, 318, 334
Unipolar method, 244
Unit, Board of Trade, 109
—— of capacity, 108
—— of current, 108
—— of EMF, 108
—— of energy, 109
—— of quantity, 108
—— of resistance, 108
Uranium rays, 349
Urate of soda, 239
Uviol lamp, 315

V

Valve, Nodon, 2, 6, **295**
—— tube, 327-329, 331, 332
Vaso-motor paralysis, 59, 65, 226, 371
Venules, dilated, 244
Vertigo, laryngeal, 215
Villard valve-tube (*see* Valve-tube)
Visceral symptoms in hysteria, 68
Visceroptosis, 95
Vision, yellow, 206
Visual fields, contracted, 58, 67, 74
Volkmann's contracture, 199
Volt, 107
Volt-regulator, **26**, **27**, 32, 291, 302
Volta, 105
Voltaic pile, 105
Voltameter, 108
Vomiting, 68

W

Wasting, general, 141
——, muscular, 140, 148, 149
Watt, 109, 317
Watt-hour, 109
Wave-lengths, 364
Wehnelt's interruptor, 325
Weir-Mitchell treatment, 61, 86
Werdnig-Hoffmann atrophy, 306
Wire-brush, 59, 62, 65, 71, 86, 103
Wire connections, 21-22
Wire, platinoid, 26
Wimshurst static machine, 34, 354-357
Wrist, dropped, 183
Writer's cramp, 222
Wry-neck, 224

X

X-ray couch, 347
—— dermatitis, 338, 342
——, dosage of, 337
—— ophthalmia, 81
X-ray photography, 341
——, precautions necessary, 347
——, sources of, 321
—— stereoscopic pictures, 348
—— therapeutic effects, 342
—— ulcers, 338
——, uses of, 338
—— wave-length, 334, 364

Y

Yellow vision, 206
Yttria, 316

Z

Zinc element, 117
—— ions, 239
Zirconia, 316
Zone, hysterogenetic, 67
——, peripolar, 125
——, polar, 125
Zoster, herpes, 235, 346

PRINTED BY
CASSELL & COMPANY, LIMITED, LA BELLE SAUVAGE
LONDON, E.C.

9